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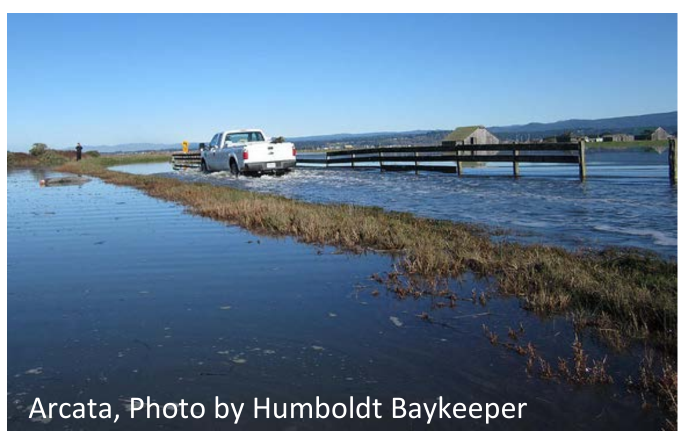
CALIFORNIA COASTAL COMMISSION DRAFT SEA-LEVEL RISE POLICY GUIDANCE

Public Review Draft
Comment Period:
October 14, 2013 - January 15, 2014

Sunset Beach, Photo by Mario Fernandez

Chula Vista, Photo by Lisa Cox


San Francisco, Photo by Mike Baird


Arcata, Photo by Humboldt Baykeeper

REQUEST FOR COMMENTS

California Coastal Commission staff is now seeking comments on the Draft Sea-Level Rise Policy Guidance. The Draft Policy Guidance was released for public review on the Commission's website on October 14, 2013. Please send written comments on the Draft Policy Guidance via email or by U.S. mail to the address below.

California Coastal Commission
c/o Sea-level Rise Work Group
45 Fremont Street, Suite 2000
San Francisco, CA 94105
Email: SLRGuidanceDocument@coastal.ca.gov

Oral comments will be welcome at Commission public hearings in November, December, 2013 and/or January, 2014. Please check the Commission's website for updates on hearing dates.

Please send your comments as soon as possible and no later than **5 pm Wednesday, January 15, 2014.** The 90-day comment period is provided to maximize public, local government, and agency participation in the discussion and review of the Commission's Draft Sea-Level Rise Policy Guidance.

After the January 2014 Commission meeting and close of the written public comment period on January 15, 2014, Commission staff will address feedback from the Commission members, agencies, local governments, and the public and will prepare a proposed Final Sea-Level Rise Policy Guidance document. The Final Policy Guidance will be brought back to the Commission at a future public hearing.

Please email questions to **SLRGuidanceDocument@coastal.ca.gov** or call Hilary Papendick at (415) 904-5294 or Lesley Ewing at (415) 904-5291. Thank you in advance for your review and comments.

EXECUTIVE SUMMARY

Climate change is upon us, and almost every facet of California's natural and built environment is being affected. Increasing global temperatures are causing significant effects at global, regional, and local scales. In the past century, average global temperature has increased by about 0.8°C (1.4°F), and average global sea level has increased by 17 to 21 centimeters (7 to 8 inches) (IPCC, 2013). Sea level at the San Francisco tidal gauge has risen 20 centimeters (8 inches) over the past century, and the National Research Council projected that sea level may rise by as much as 140-165 centimeters (55-65 inches) in California by 2100 (NRC, 2012). The Coastal Commission has developed this guidance to help California's coastal communities prepare for the effects of sea-level rise.

The economic impacts of sea-level rise in California could be severe. Many parts of the state's $1.9 trillion economy – including coastal tourism, commercial fisheries, coastal agriculture, and ports – are at risk from sea-level rise. In addition to potential loses in revenue, the Pacific Institute estimates that $100 billion worth of property is at risk of flooding during a 100-year flood with a projected 1.4 meters of sea-level rise. This property includes seven wastewater treatment plants, commercial fishery facilities, marine terminals, Coastal Highway One, fourteen power plants, residential homes, and other important development and infrastructure (Heberger et al. 2009). Also, public beaches and recreational resources may be lost, and wetlands and other sensitive resources may disappear. These resources provide invaluable benefits to California, including recreation and tourism revenues, habitat for commercial fish species, enhanced water quality, and increased quality of life.

California must begin to take more proactive steps to address sea-level rise due to the significant impacts it may have on California's economy, natural systems, built environment, human health, and ultimately its way of life. This Sea-Level Rise Policy Guidance is intended to help local governments, permit applicants, and other interested parties begin to address the challenges presented by sea-level rise in California's coastal zone.

Specifically, this document provides step-by-step guidance on how to address sea-level rise in new and updated Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs) according to the policies of the California Coastal Act. LCPs and the coastal development permit process are the fundamental land use planning and regulatory governing mechanisms in the coastal zone, and it is critically important that they are based in sound science and updated policy recommendations. This document also contains guiding principles for addressing sea-level rise in the coastal zone; a description of the best available science for California on sea-level rise; specific policy guidance to effectively address coastal hazards while continuing to protect coastal resources; and background information on adaptation measures, sea-level rise science, how to establish future local water conditions in light of sea-level rise, links to useful resources and documents from other state agencies, and Coastal Act policies relevant to sea-level rise.

This guidance document is also part of a larger statewide strategy to respond to climate change. California is working on a number of important initiatives to both reduce the state's contribution to global warming through the emission of greenhouse gases, and to reduce the impacts of a changing climate to California. This guidance is being coordinated closely with many of these other initiatives, including the 2013 update to the 2009 California Adaptation Strategy (Safeguarding California Plan), 2013 update to the General Plan Guidelines, 2013 update to the California Office of Emergency Services' State Hazard Mitigation Plan and a number of other plans and programs that also affect land use development patterns and the reduction of long-term risk exposure to coastal hazards.[1] It is important these various state efforts are closely coordinated and avoid unnecessary conflict, to assure an effective statewide response to challenges such as sea-level rise. The Commission has been and will continue to participate in the coast and ocean group of a multi-state agency climate action team first established in 2008. The Commission also will continue to coordinate with other on-going state initiatives through the public review and adoption process for this guidance, to assure that the Commission's efforts to respond to sea level rise work in concert with the larger state strategy.

USING BEST AVAILABLE SCIENCE ON SEA-LEVEL RISE

California must use the best available environmental science to conduct coastal land use planning and development. The State of California supported the preparation of the 2012 National Research Council's Report, *Sea Level Rise for the Coasts of California, Oregon and Washington: Past Present and Future*, which is currently considered the best available science on sea-level rise for California. The report contains sea-level rise projections for three time periods over the coming century for north and south of Cape Mendocino (Table 1).[2] In March 2013, the State of California Sea-level Rise Guidance Document prepared by the Ocean Protection Council was updated to include the following sea-level rise projections from the NRC report.[3]

[1] See the Governor's Office of Planning and Research's webpage for a matrix of additional efforts. Available at: http://opr.ca.gov/s_publications.php

[2] The NRC Committee divided the Pacific coast for California, Oregon and Washington into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this point. North of Cape Mendocino, land is rising by 1.5 to 3.0 mm/yr as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is sinking at an average rate of about 1 mm/yr, although local rates vary widely (NRC 2012, pg 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary.

[3] Any future updates to the state guidance document will be available at http://www.opc.ca.gov/2009/12/climate-change/.

Table 1. NRC Sea-Level Rise Projections for California (NRC, 2012)

TIME PERIOD	NORTH OF CAPE MENDOCINO	SOUTH OF CAPE MENDOCINO
2000 – 2030	-4 – +23 cm (-1.56 – 9 inches)	4 – 30 cm (1.56 – 11.76 inches)
2000 – 2050	-3 – + 48 cm (-1.2 – 18.84 inches)	12 – 61 cm (4.68 – 24 inches)
2000 – 2100	10 – 143 cm (3.6 – 56.28 inches)	42 – 167 cm (16.56 – 65.76 inches)

In addition to these sea-level rise projections, the 2012 NRC report provides information on the impacts of sea-level rise in California. According to the report, sea-level rise will cause flooding and inundation, an increase in coastal erosion, changes in sediment supply and movement, and saltwater intrusion to varying degrees along the California coast. These effects in turn could have a significant impact on the coastal economy and could put important coastal resources and coastal development at risk, including ports, marine terminals, commercial fishing infrastructure, public access, recreation, wetlands and other coastal habitats, water quality, biological productivity in coastal waters, coastal agriculture, and archeological and paleontological resources.

PRINCIPLES FOR ADDRESSING SEA-LEVEL RISE IN THE COASTAL ZONE

This guidance is rooted in certain fundamental guiding principles, many of which derive directly from the requirements of the Coastal Act. In this respect, the principles are not new, but rather generally reflect the policies and practices of the Commission since its inception in addressing coastal hazards and the other resource and development policies of the Act. Each of the four groups of principles below embodies important concepts that are specifically and increasingly raised by the challenges of rising sea levels. This guidance builds on the cumulative knowledge and experience of the agency to help identify practical guidance for addressing sea-level rise in the California coastal zone, consistent with these principles and the statewide policies of the California Coastal Act.

A. Use Science to Guide Decisions [Coastal Act Sections 30006.5; 30335.5]

1. Acknowledge and address sea-level rise as necessary in planning and permitting decisions.
2. Use the best available science to determine locally relevant (context-specific) sea-level rise projections for all stages of planning, project design, and permitting reviews.
3. Recognize scientific uncertainty by using scenario planning and adaptive management techniques.

B. Minimize Coastal Hazards through Planning and Development Standards [Coastal Act Sections 30253, 30235; 30001, 30001.5]

4. Avoid significant coastal hazard risks where feasible.
5. Minimize hazard risks to new development over the life of authorized structures.

6. Avoid or minimize coastal resource impacts when addressing risks to existing development.
7. Account for the social and economic needs of the people of the state; assure priority for coastal-dependent and coastal-related development over other development.
8. Property owners should assume the risks associated with new development in hazardous areas.

C. Maximize Protection of Public Access, Recreation, and Sensitive Coastal Resources [Coastal Act Chapter 3; Section 30235]

9. Provide for maximum protection of public beach and recreational resources in all coastal planning and regulatory decisions.
10. Maximize natural shoreline values and processes and embrace green infrastructure and living shorelines; avoid the perpetuation of shoreline armoring.
11. Address other potential coastal resource impacts (wetlands, habitat, scenic, etc.) from hazard minimization decisions, consistent with the Coastal Act.
12. Address the cumulative impacts and regional contexts of planning and permitting decisions.
13. Require mitigation of unavoidable public coastal resource impacts related to permitting and shoreline management decisions.
14. Include best available information on resource valuation in mitigation of coastal resource impacts.

D. Maximize Agency Coordination and Public Participation [Coastal Act Chapter 5; Sections 30006; 30320; 30339; 30500; 30503; 30711]

15. Coordinate planning and regulatory decision making with other appropriate state, local, and federal agencies; support research and monitoring efforts.
16. Consider conducting vulnerability assessments and adaptation planning at the regional level.
17. Provide for maximum public participation in planning and regulatory processes.

GUIDANCE FOR LOCAL COASTAL PROGRAMS

This document provides a step-by-step process for incorporating sea-level rise and adaptation planning into new and amended Local Coastal Programs (LCPs). These steps, summarized below in text and in Figure 1, can be tailored to fit the needs of individual communities and to address the specific coastal resource and development issues of a community, such as dealing with bluff erosion or providing for effective redevelopment, and urban infill and concentration of development in already developed areas. Coastal Commission staff will be available to consult with local government planners during this process.

Step 1. Determine a range of sea-level rise projections relevant to LCP planning area or segment. Local governments should use the best available science—which, as reported in the State of California Sea Level Rise Guidance Document,[4] is currently the 2012 NRC Report—to identify a range of sea-level rise projections for their region. Next, they should modify those projections to account for local conditions.

Step 2. Identify potential physical sea-level rise impacts in LCP planning area/segment. Using the sea-level rise projections identified in step 1, planners should determine the potential future impacts of sea-level rise hazards, including inundation, storm flooding, wave impacts, erosion, or saltwater intrusion into freshwater resources.

Step 3. Assess potential risks from sea-level rise to coastal resources and development in LCP planning area/segment. Planners should determine what development and resources, including those addressed in Chapter 3 of the Coastal Act, are at risk from sea-level rise hazards. As part of this step, planners should assess whether the planning area or segment land uses are feasible given sea-level rise impacts and determine whether land uses will need to be revised. This process will enable planners to prioritize resources at risk in the next steps of the planning process.

Step 4. Identify adaptation measures and LCP policy options. Certified LCPs will already have land use policies, standards, and ordinances that implement Chapter 3 policies related to hazard avoidance and mitigation; however, these may need to be amended to address sea-level rise impacts. Two types of updates will be necessary to address sea-level rise: policies and ordinances that apply to all development exposed to sea-level rise, and policies and land use changes to address specific risks in a particular portion of the planning area. Chapter 4 and Appendix C of this document outline possible sea-level rise adaptation measures that can be employed at both the community-level and the site-specific level.

Step 5. Develop or update LCP and certify with California Coastal Commission. The next step is to incorporate the LCP policies that address sea-level rise into a new LCP or an updated LCP amendment, and submit the document to the Coastal Commission for certification. Developing or updating the LCP should be completed in close coordination with Coastal Commission staff. Once the LCP, including the Land Use Plan and Implementing Ordinances, are amended and certified with revised policies to address sea-level rise, local governments will implement the certified policies through the coastal development permit process. Local governments should identify technical assistance and pursue funding and partnerships necessary to support this action.

Step 6. Monitor and re-evaluate implementation of the LCP and specific measures as needed. Planners should then identify key resources to monitor and plan periodic updates to their LCPs to incorporate new science relevant to their area.

[4] Available at http://www.opc.ca.gov/2009/12/climate-change/.

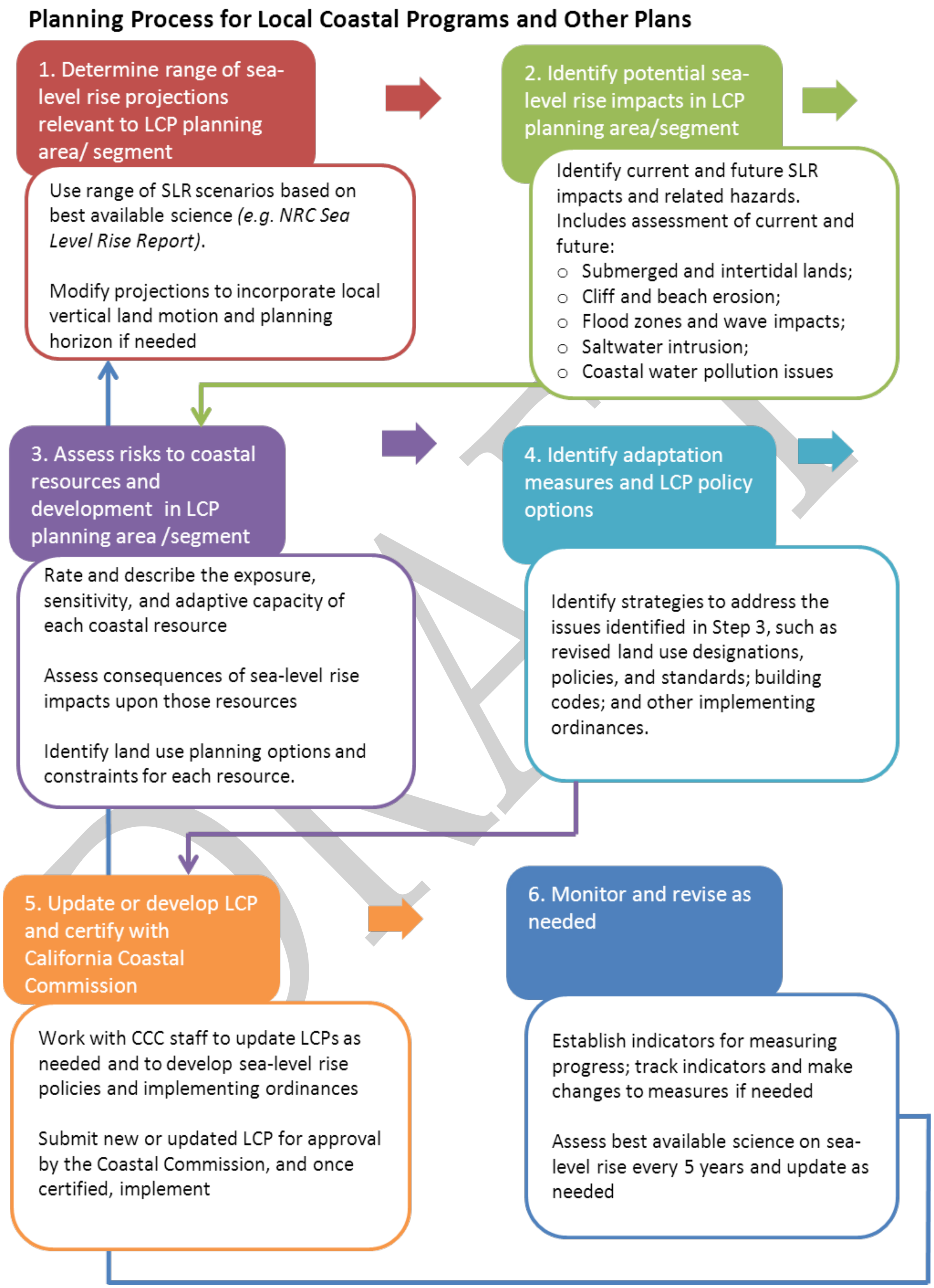


Figure 1. Flowchart for Addressing Sea-Level Rise in Local Coastal Programs and other Plans

GUIDANCE FOR COASTAL DEVELOPMENT PERMITS

New development within the coastal zone generally requires a Coastal Development Permit (CDP). Many projects reviewed through the CDP application process already examine sea-level rise as part of the hazards analysis. This document offers a step-by-step outline of how to conduct such an analysis as a standard part of the CDP application process. The goal of these steps is to ensure careful attention to minimizing risk to development and avoiding impacts to coastal resources over the life of the project. Coastal Commission staff will be available to consult with applicants during this process.

Step 1. Establish the projected sea-level rise range for the proposed project. Applicants should use the best available science—which, as reported in the State of California Sea Level Rise Guidance Document,[5] is currently the 2012 NRC Report—to identify a range of sea-level rise projections for the project's planning horizon, or, alternatively, for the time periods identified in the 2012 NRC report: 2030, 2050, and 2100.

Step 2. Determine how impacts from sea-level rise may constrain the project site. Though LCPs often provide an analysis of sea-level rise hazards, projects within the coastal zone often require a more site-specific analysis of the probable effects of sea-level rise. This analysis should look at how erosion, structural and geologic stability, flooding and inundation, flood elevation, and other impacts may limit where the project can feasibly be sited under the sea-level rise scenarios identified in step 1. Appendix B explains how to incorporate sea-level rise into analyses of changes to the intertidal zone, areas of future erosion, impacts from waves and wave runup, and inclusion of extreme events.

Step 3. Determine how the project may impact coastal resources, considering the influence of future sea-level rise upon the landscape. Coastal resources should then be identified, and feasible and safe project sites should be selected that avoid impacts to those resources. This analysis should include potential impacts of any sea-level rise adaptation strategies that may be used over the lifetime of the project, along with inland/upland requirements for buffers or retreat.

Step 4. Identify alternatives to avoid resource impacts and minimize risks. If there are potential conflicts with coastal resources, the project design should focus on alternatives that will be protective of coastal resources throughout the expected life of the development. The project should avoid sea-level rise hazards if possible, and minimize hazard exposure if avoidance is infeasible. If it is not feasible to site or design a structure to be safe from sea-level rise over the anticipated life of the structure, the applicant should develop a sea-level rise adaptation strategy, including steps to relocate or modify the development as needed to prevent risks to the development or to coastal resources as part of the alternatives analysis. The CDP

[5] Available at http://www.opc.ca.gov/2009/12/climate-change/.

should also identify any design constraints that would prevent the implementation of any of those adaptation measures. New development should not in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.

Step 5. Finalize project design and submit CDP. The applicant should work with the planning staff to complete the CDP application and develop a project that is consistent with the Coastal Act, protective of coastal resources, and minimizes risks from sea-level rise to the greatest extent feasible.

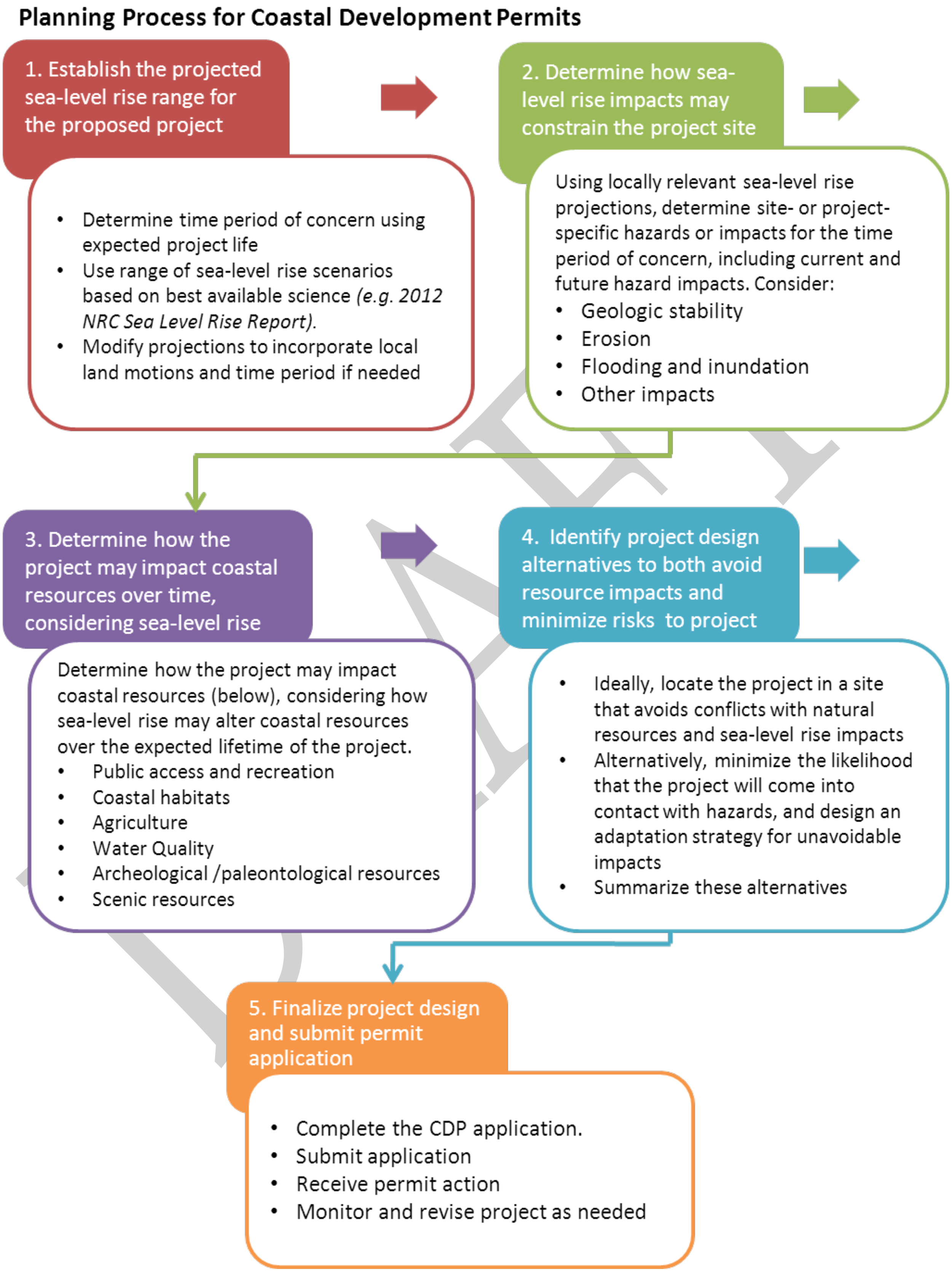


Figure 2. Flowchart for Addressing Sea-Level Rise in Coastal Development Permit

ADDITIONAL INFORMATION

In summary, this guidance provides step-by-step approaches for addressing sea-level rise in LCPs and CDPs. It also offers extensive Appendices with supplemental information, including:

- Detailed information on the drivers of sea-level rise and sea-level rise projections
- A step-by-step methodology for developing local hazard conditions based on regional sea-level rise projections, which is applicable to both LCPs and CDPs
- Descriptions of many sea-level rise adaptation measures
- Lists of other useful resources and references
- Examples of sea-level rise adaptation documents from other state agencies
- Descriptions of specific Coastal Act policies relevant to sea-level rise and coastal hazards

CONTEXT OF THIS DOCUMENT

Commission staff recognizes that this guidance is part of a larger body of work on climate change by State agencies, regional collaborations, local leadership, academic research and other organizations. Many of these efforts are included as resources in Appendix D and Appendix E. Staff encourages users of the document to take advantage of existing resources, collaborate with others, and share best practices as much as possible.

Finally, this document is intended to function as guidance, not regulations. It does not govern the planning and regulatory actions that the Commission or local governments may take under the Coastal Act and subject to the applicable requirements of the Coastal Act, the Coastal Zone Management Act, certified LCPs and other applicable laws and regulations as applied in the context of the evidence in the record for that action.

TABLE OF CONTENTS

List of Tables

List of Figures

Commonly Used Acronyms and Agency Names

Terms:

LCP – Local Coastal Program
CDP – Coastal Development Permit
CCT – California Coastal Trail
GHG – Greenhouse Gas
SLR – Sea-Level Rise

Agency Names:

CCC/Commission – California Coastal Commission
BCDC- San Francisco Bay Conservation and Development Commission
CNRA- California Natural Resources Agency
CO-CAT – Coast and Oceans Climate Action Team
Conservancy – California State Coastal Conservancy
OES – California Governor's Office of Emergency Services
OPC – California Ocean Protection Council
OPR – California Governor's Office of Planning and Research
State Lands- California State Lands Commission
State Parks - California Department of Parks and Recreation

I. INTRODUCTION

Climate change is happening now. Rapidly melting ice caps, rising sea levels, extreme heat waves, droughts, fires, and floods are just a few of the secondary effects of climate change. These phenomena are having profound effects on our coast and are changing coastal management planning and decision-making at global, national, state, regional, local, and individual levels.

The California Coastal Commission staff prepared this guidance to provide a framework for addressing sea-level rise in Local Coastal Programs and Coastal Development Permits. The intended audience for this document includes the Commission, Commission staff, local governments, other public agencies, applicants, members of the public, and others who are interested in how to implement and comply with the California Coastal Act (Coastal Act) while taking steps to address sea-level rise.

Given current trends in greenhouse gas emissions, sea levels are expected to rise at an accelerating rate in the future, and scientists project an increase in California's sea level of up to 61 centimeters (24 inches) by 2050 and 167 centimeters (65.7 inches) by 2100, relative to year 2000 (NRC, 2012). Until mid-century, the most damaging events for the California coast will likely be dominated by large El Niño-driven storm events in combination with high tides and large waves. Eventually, sea level will rise enough that even small storms will cause significant damage, and large events will have unprecedented consequences (Caldwell et al., 2013).

Many of the potential impacts of sea-level rise directly overlap with the Coastal Commission's planning and regulatory responsibilities under the Coastal Act. Sea-level rise increases the risk of flooding, coastal erosion, and saltwater intrusion into freshwater supplies, which have the potential to threaten many of the resources that are integral to the California coast, including coastal development, coastal access and recreation, habitats (e.g. wetlands, coastal bluffs, dunes, and beaches), coastal agricultural lands, and cultural resources. Community character and scenic quality could be at risk as well. Impacts to coastal habitats are compounded by the fact that California already has lost 90% of its coastal wetlands, and erosion and flooding currently pose risks to many of the remaining coastal ecosystems (CA Natural Resources Agency, 2010). In addition, many possible responses to sea-level rise, such as construction of barriers or armoring, can have adverse impacts on coastal resources. Beaches, wetlands, and other habitat backed by fixed or permanent development will not be able to migrate inland as sea level rises, and will become permanently inundated over time, which presents serious concerns for future public access and habitat protection. The Coastal Act mandates the Commission to protect public access to the coast, open space, and coastal habitats, and other sensitive resources, as well as provide for priority visitor-serving and coastal-dependent or related development while minimizing the risks of coastal hazards. This guidance document has been created to help managers continue to achieve these goals in the face of sea-level rise.

California has approximately 21 million people currently living in coastal counties (as of 2010) (CA Department of Finance, 2013), and it supports a $40 billion ocean economy (National Ocean Economics Program, 2010). Many aspects of the coastal economy, as well as California's broader economy, are at risk from sea-level rise, including coastal-related tourism, agriculture, transfer of goods and services through ports and transportation networks, commercial fishing and aquaculture facilities, and beaches and recreation opportunities, including surfing. In addition, sea-level rise poses particular challenges for communities dependent on at-risk industries and for communities already suffering from economic hardship, which have limited capacity to adapt. These issues underscore the importance of taking proactive steps to prepare for sea-level rise, and to protect the coastal economy, California livelihoods, and coastal resources and the ecosystem services they provide.

RECENT EFFORTS TO PREPARE FOR SEA-LEVEL RISE

The State of California has long been a leader in preparing for sea-level rise, and in 2008, the Governor issued an Executive Order (S-13-08) directing state agencies to prepare guidance on sea-level rise and to address sea-level rise in any state projects located in vulnerable areas. In the past five years, state agencies have worked collaboratively to accomplish a variety of different actions related to sea-level rise adaptation, including developing a California Climate Adaptation Strategy (2009 and 2013 update in progress), passing a State Sea-Level Rise Resolution (2011), establishing State Sea-Level Rise Guidance (2013), and completing an Adaptation Planning Guide for local governments (2012). Ten state and federal agencies[6] commissioned the National Academy of Sciences report (2012) to improve understanding of sea-level rise projections for California. Much of this work has been accomplished through the Coasts and Oceans Climate Action Team (CO-CAT), of which the Commission has been a member.

This guidance document is also part of a larger statewide strategy to respond to climate change. California is working on a number of important initiatives to both reduce the state's contribution to global warming through the emission of greenhouse gases, and to reduce the impacts of a changing climate to California. This guidance is being coordinated closely with many of these other initiatives, including the 2013 update to the 2009 California Adaptation Strategy (Safeguarding California Plan), 2013 update to the General Plan Guidelines, 2013 update to the California Office of Emergency Services' State Hazard Mitigation Plan and a number of other plans and programs that also affect land use development patterns and the reduction of long-term risk exposure to coastal hazards.[7] It is important these various state efforts are closely coordinated and do not conflict, to assure an effective response to challenges such as sea-level rise.

Sea-level rise is not a new concern for the Commission. The Coastal Act policies on hazard avoidance and coastal resource protection provide the basis for the Commission to consider the impacts of sea-level rise. As a part of developing permit and Local Coastal Program recommendations for Commission consideration and pursuant to applicable Coastal Act policies,

[6] The assessment of sea-level rise was commissioned by California Department of Water Resources, California Energy Commission, California Department of Transportation, California State Water Resources Control Board, California Ocean Protection Council, Oregon Watershed Enhancement Board, Washington Department of Ecology, National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE), and U.S. Geological Survey (USGS).

[7] See the Governor's Office of Planning and Research's webpage for a matrix of additional efforts. Available at: http://opr.ca.gov/s_publications.php

the Commission staff has long considered sea-level rise and erosion rates and other effects of a dynamic climate in its analysis and its recommendations to the Commission. The Commission coordinates this work with other state and federal agencies, local governments, academic institutions, non-profit organizations, citizen groups, permit applicants, property owners, and others.

Coastal Commission reports and briefing on sea-level rise: The Commission has documented its sea-level rise adaptation and climate change efforts in numerous papers and briefings, including:

- 1989 Report: *Planning for Accelerated Sea-Level Rise along the California Coast*
- 2001 Report: *Overview of Sea Level Rise and Some Implications for Coastal California*
- 2006 Briefing: *Discussion Draft: Global Warming and the California Coastal Commission*
- 2008 Briefing: *A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues for a Briefing to the Coastal Commission*
- 2008 White paper: *Climate Change and Research Considerations*
- 2010 Briefing: *A Summary of the Coastal Commission's Involvement in Sea Level Rise Issues for a Briefing to the Coastal Commission*

State agency policies and guidance on sea-level rise: As a result of the Executive Order S-13-08 and agency needs for guidance, many state agencies have developed sea-level rise policies and guidance documents. For example: The San Francisco Bay Conservation and Development Commission (BCDC) amended the *San Francisco Bay Plan* to update its policies regarding sea-level rise; the California State Coastal Conservancy (Conservancy) established climate change policies, application guidelines for sea-level rise, and climate ready principles; and the California Department of Transportation (CalTrans) developed guidance on incorporating sea-level rise into the planning and development of Project Initiation Documents, and is in the process of developing "hot spot" vulnerability assessment of transportation infrastructure at risk from sea-level rise. Other agencies including the California Department of Parks and Recreation and the California State Lands Commission are in the process of developing guidance. The California Department of Fish and Wildlife, Department of Boating and Waterways, Department of Water Resources are all actively addressing sea-level rise and have taken steps to conduct research on sea-level rise impacts, integrate sea-level rise into planning documents, and educate staff on climate change impacts (See Appendix E for a description of these efforts).

Other efforts: Sea-level rise planning efforts taking place at the local, regional, and state levels in California, as well as from other states and nations, helped inform this guidance. In addition, the Commission staff reviewed scientific publications on sea-level rise and climate change, adaptation guidebooks, and existing adaptation principles and best practices described in documents such as Indicators of Climate Change in California (Cal EPA, 2013), Adaptation Planning Guide (CA Natural Resources Agency, 2012), Adapting to Sea Level Rise: A Guide for California's Coastal Communities (Russell and Griggs, 2012), National Wildlife Federation Climate Change Adaptation Principles (2011), Ecosystem Adaptation to Climate Change in California: Nine Guiding Principles (Resources Legacy Fund, 2012), Climate Smart Principles by Point Blue (2013), and California State Coastal Conservancy Climate Ready Programmatic

Priorities (2013), and applied relevant information to the guidance where applicable and consistent with the Coastal Act.

2013-2014 Funding for LCP updates: The 2009 California Climate Adaptation Strategy identified amendments to Local Coastal Programs as a key strategy for addressing sea-level rise in California. Strategy 4e of the Coasts and Oceans Chapter states: "…all coastal jurisdictions, in coordination with the Coastal Commission, should begin to develop amended LCPs that include climate change impacts" (CA Natural Resources Agency, 2009, pg 77). However, there are significant funding constraints at both the Commission and local government levels that limit LCP amendments. To address this issue, the Ocean Protection Council has approved $2.5 million in grant funds for local governments to update LCPs to address sea-level rise, and as of June 2013, the California Coastal Conservancy, Ocean Protection Council, and Coastal Commission are in the process of administering the new grant program.

In addition, Governor Brown and California Legislature approved an augmentation of $4 million to the fiscal year 2013-2014 budget of the Coastal Commission ($3 million for state operations and $1 million for grants to local governments) for local governments and the Coastal Commission to prepare, update, amend, and review LCPs including with an emphasis on climate change issues. The Coastal Commission is working with the Administration to provide information to support long-term funding to address the critical need to update LCPs and include climate change adaptation.

PURPOSE AND SCOPE OF GUIDANCE DOCUMENT

This document contains recommendations for addressing sea-level rise in Local Coastal Programs (LCPs), Coastal Development Permits (CDPs), and other actions pursuant to the Coastal Act. Specifically, the document provides information on the current best available science on sea-level rise, techniques for assessing sea-level rise vulnerability, and strategies for reducing risks from sea-level rise. Its goal is to minimize risks to development and coastal resources from hazards and hazards response, avoid impacts to coastal resources on a dynamic coast, and maximize public access opportunities now and in the future, in accordance with the Coastal Act. There are many ways to evaluate and minimize the risks from sea-level rise, and Commission staff understands that different types of analyses and actions will be appropriate depending on the type of project or planning effort. As a result of the multiple purposes for this report, it is intended for a broad audience.

This guidance is not a regulatory document and does not directly govern the actions that the Commission or local governments may take under the Coastal Act. Any planning or regulatory action that the Commission or local governments may take is subject to the applicable requirements of the Coastal Act, the federal Coastal Zone Management Act, certified Local Coastal Programs, and other applicable laws and regulations as applied in the context of the evidence in the record for that action.

Finally, this guidance does not address how sea-level rise may involve private property rights and takings issues in specific cases. Accelerating sea-level rise may raise difficult issues with respect to what kinds and intensities of development are allowable or that must be allowed, in specific areas threatened by sea-level rise in order to avoid a “taking” of property within the meaning of the United States and California constitutions. Coastal Act Section 30010 prohibits the Commission, ports, and local governments from exercising their coastal development permitting authority in a manner that will take or damage private property without just compensation. Evaluation of whether a particular regulatory action would constitute a taking involves consideration of a wide range of site- and project-specific factors. How to perform this evaluation is outside the scope of these Guidelines. Agencies implementing the Coastal Act should obtain legal advice regarding specific situations that raise takings concerns.

Sea-level rise is one of many climate change impacts that will affect coastal resources and development. The Coastal Act supports the consideration of other relevant climate change impacts in decision-making, and the Commission intends to provide guidance on a range of anticipated climate change impacts in the future.

II. PRINCIPLES FOR ADDRESSING SEA-LEVEL RISE IN THE COASTAL ZONE

The following principles are intended to guide sea-level rise adaptation efforts at the Coastal Commission, and many of the principles derive directly from the requirements of the Coastal Act. Each of the four groups of principles below embodies important concepts that are specifically and increasingly raised by the challenges of rising sea levels. This guidance builds on the cumulative knowledge and experience of the Commission to help identify practical guidance for addressing sea-level rise consistent with these principles and the statewide policies of the California Coastal Act.

A. USE SCIENCE TO GUIDE DECISIONS [Coastal Act Sections 30006.5; 30335.5]

1. **Acknowledge and address sea-level rise as necessary in planning and permitting decisions.** Integrate sea-level rise into all appropriate coastal management and decision-making processes, including Local Coastal Programs (LCPs), Port Master Plans (PMPs), Public Works Plans (PWPs), Long Range Development Plans (LRDPs) and other plans, Coastal Development Permits (CDPs), federal consistency decisions, public access dedication efforts, and habitat preservation and restoration. Addressing sea-level rise encompasses current and future sea levels as well as changing risks and coastal conditions associated with sea level. Sea-level rise should be integrated into existing coastal hazard, shoreline change, and extreme event analyses, including any potential changes to flooding, inundation, wave impacts, erosion, sediment supplies, extreme events, and saltwater intrusion. Plans and projects should include a sea-level rise vulnerability and risk assessment and describe any actions needed to minimize risks to coastal resources and development due to sea-level rise, including land use designations, new policies, or increased setbacks or design changes.

2. **Use the best available science to determine locally relevant (context-specific) sea-level rise projections for all stages of planning, project design, and permitting reviews.** The best available science should be used in planning and regulatory actions. With respect to sea level, this means that the best available sea-level rise projections should be used to establish a range of locally-relevant future water levels and shoreline change, and to assess vulnerability and risks from sea-level rise. Simple extrapolation of historic trends should not be used. This science may include peer-reviewed and well-documented climate science, adaptation strategies, and management practices. At the time of this report's publication, the best available science on sea-level rise in California is the 2012 National Research Council (NRC) Report, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future* (NRC, 2012) (See Table 2). The State of California Sea-Level Rise Guidance Document (March 2013) includes projections that are based on the NRC report and the state guidance document may be updated in the future to reflect significant changes in the best available science.[8] This

[8] Available at http://www.opc.ca.gov/2009/12/climate-change/.

NRC report contains regional sea-level rise projections for North and South of Cape Mendocino.[9] Where local vertical land motion or other conditions vary considerably from the regional average used in the projections (such as vertical land motion trends in parts of Humboldt Bay and the Eel River Estuary), these projections should be modified to account for local conditions.

Table 2. NRC Sea-Level Rise Projections for California (NRC, 2012)

TIME PERIOD	NORTH OF CAPE MENDOCINO[10]	SOUTH OF CAPE MENDOCINO
2000 – 2030	-4 – +23 cm (-1.56 – +9 inches)	4 – 30 cm (1.56 – 11.76 inches)
2000 – 2050	-3 – + 48 cm (-1.2 – +18.84 inches)	12 – 61 cm (4.68 – 24 inches)
2000 – 2100	10 – 143 cm (3.6 – 56.28 inches)	42 – 167 cm (16.56 – 65.76 inches)

The science on sea-level rise is constantly evolving, and some of the processes that are not fully understood (e.g., ice sheet dynamics) could potentially have large effects on future sea-level rise. The Commission will re-examine the best available science at least every 5 years or as needed with the release of new information on sea-level rise.[11] In addition, Commission staff intends to submit a periodic status report to the Commission describing updates on the best available science and adaptation practices, and any potential recommended changes to the guidance document.

3. **Recognize and address scientific uncertainty using scenario planning and adaptive management techniques.** Given the uncertainty in the magnitude of future sea-level rise, projects and plans should use scenario-based analysis to examine the full range of possible shoreline changes and sea-level rise risks. As appropriate, projects, resource management plans, and planning updates should use an adaptive management framework with regular monitoring and reassessments. An adaptive management framework involves learning and dynamic adjustment in order to accommodate uncertainty.

[9] The NRC Committee divided the Pacific coast for California, Oregon and Washington into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this point. North of Cape Mendocino, land is rising by 1.5 to 3.0 mm/yr as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is sinking at an average rate of about 1 mm/yr, although local rates vary widely (NRC 2012, pg 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary.

[10] Since portions of Humboldt Bay are experiencing subsidence, and thus differ from the regional uplift conditions, the projections for north of Cape Mendocino may not be appropriate for use within parts of Humboldt Bay. See Appendix B for additional discussion about vertical land movement and relative sea-level rise.

[11] Major scientific reports include the release of the 2013 National Climate Assessment and the IPCC 5th Assessment Report, which is due for phased releases in 2013-2014.

B. MINIMIZE COASTAL HAZARDS THROUGH PLANNING AND DEVELOPMENT STANDARDS [Coastal Act Sections 30253; 30235; 30001, 30001.5]

4. **Avoid significant coastal hazard risks where feasible.** Section 30253 of the Coastal Act requires new development to minimize risks to life and property in areas of high geologic and flood hazard. The strongest approach for minimizing hazards is to avoid new development within areas vulnerable to flooding, inundation, and erosion. Hazard avoidance also ensures stable site conditions without the need for long-term financial and resource commitments for protective devices. Methods to direct new development away from hazardous locations include changing zoning and land use intensity, establishing conservation easements or open space designations, and siting structures a safe distance away from hazard areas (setbacks). Hazard avoidance efforts should not result in impacts to coastal resources or encroachment into coastal habitats.

5. **Minimize hazard risks to new development over the life of the authorized structures.** In situations where hazards due to sea-level rise cannot be avoided, new development should minimize risks over the life of the structure, without the use of bluff retaining or shoreline protection devices. New structures in hazard areas should include provisions to ensure structures are modified, relocated, or removed when they become threatened by natural hazards, including sea-level rise, in the future. Risk minimization efforts should not result in impacts to coastal resources or encroachment into coastal habitats.

6. **Avoid or minimize coastal resource impacts when addressing risks to existing development**. Existing coastal development should avoid or minimize impacts to coastal resources in any repairs, maintenance or renovations. Sea-level rise protection measures for existing development should be analyzed for coastal resource impacts, and any impacts should be minimized. Renovations or redevelopment that constitutes new development should avoid or minimize risks and protect coastal resources in accordance with guidance for new development.

7. **Account for the social and economic needs of the people of the state; assure priority for coastal-dependent and coastal-related development over other development.** In planning and project development concerning sea-level rise, assure that the social and economic needs of the people of the state are accounted for in accordance with Coastal Act Section 30001.5 (b), with special consideration for working persons employed within the coastal zone (Coastal Act Section 30001 (d)). Coastal-dependent and coastal-related development may necessarily need to be sited in areas at risk from sea-level rise, and these developments should be sited and designed to minimize risks from sea-level rise and impacts to coastal resources.

8. **Property owners should assume the risks associated with new development in hazardous areas.** LCPs and permits should require property owners to assume the risks of developing in a hazardous location (often referred to as internalizing risk), and should make it clear that property owners are responsible for modifying, relocating or removing new development if it is threatened in the future. In addition, since impacts to natural

resources result in economic and quality of life losses, any actions to minimize risks to new development should not result in encroachment onto public lands or in impacts to coastal resources. To accomplish this, an LCP can include deed restriction requirements for hazardous areas, establish hazard abatement districts, or other strategies that require that property owners take responsibility for modifying, relocating, or removing development should it become threatened by natural hazards like sea-level rise. For a new development project potentially subject to future erosion, the permit should include a “no future seawall” deed restriction that requires property owners to waive the right to any future shoreline protection.

C. MAXIMIZE PROTECTION OF PUBLIC ACCESS, RECREATION, AND SENSITIVE COASTAL RESOURCES [Coastal Act Chapter 3; Section 30235]

9. **Provide for maximum protection of public beach and recreational resources in all coastal hazard planning and regulatory decisions.** The Coastal Act requires the provision and protection of maximum public access and recreation, consistent with Section 30252. In all planning and regulatory efforts, identify potential impacts from sea-level rise to public access and recreation opportunities, and develop and carry out a plan to mitigate impacts. Some options to maximize and enhance public access and recreation in light of sea-level rise include establishing new public access areas, elevating or moving trails inland when threatened by sea level, developing or modifying beach management plans to accommodate changes in sea level, or removing barriers that contribute to the loss of beach and recreation areas.

10. **Maximize natural shoreline values and processes; avoid the perpetuation of shoreline armoring.** If existing development (both private and public) is threatened by sea-level rise hazards, it should employ the least environmentally damaging feasible alternatives and minimize hard shoreline protection. Priority should be given to options that enhance and maximize coastal resources and access, including innovative nature-based approaches such as living shoreline techniques or managed/planned retreat. In some situations, protection of existing structures may include the use of traditional hard shoreline protection devices (as permitted by the Coastal Act under certain conditions). If shoreline protection is necessary and allowable under the Coastal Act, use the least-environmentally damaging alternative, incorporate projections of sea-level rise into the design of protection, and limit the time-period of approval, for example, to the life of the structure the device is protecting. Major renovations, redevelopment, or other new development should not rely upon existing shore protective devices for site stability or hazard protection. Where feasible, existing shoreline protection that is no longer needed should be phased out.

11. **Address other potential coastal resource impacts (wetlands, habitat, scenic, etc.) from hazard minimization decisions, consistent with the Coastal Act.** Actions to address sea-level rise in LCPs or permits should not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability. For example, siting and design of new development should not only avoid sea-level rise

hazards, but also ensure that the development does not have unintended adverse consequences that impact sensitive habitats or species in the area.

12. **Address the cumulative impacts and regional contexts of planning and permitting decisions.** Sea-level rise will have impacts at both the site-specific and regional scales. In addition to the evaluation of site-specific sea-level rise impacts, LCPs and projects should evaluate the broader region-wide impacts, in two different contexts. First, the LCP or project should evaluate how sea-level rise impacts throughout an entire littoral cell or watershed could affect the LCP jurisdiction or project. Second, LCPs and projects should evaluate how options to adapt to sea-level rise could result in cumulative impacts to other areas in the littoral cell or watershed, and should take actions to minimize any impacts. While some smaller scale projects may focus on the impacts to a single site, it is crucial to consider regional impacts and any cumulative impacts within a larger planning context in a LCP or other larger-scale analysis. These larger-scale impacts are best addressed in an LCP but may also need to be addressed at a project level within a CDP.

13. **Require mitigation of unavoidable public coastal resource impacts related to permitting and shoreline management decisions.** For unavoidable public resource impacts, require mitigation of resource impacts over the life of the structure as a condition of approval for the development permit. For example, for any wetlands or other sensitive habitat lost due to new development, require the landowner to conserve or restore wetland habitat. For sand supply or public recreation impacts due to armoring and the loss of sandy beach from erosion in front of shoreline protection devices, require a sand mitigation fee or other necessary mitigation fees or provide other commensurate in-kind mitigations.

14. **Include best available information on resource valuation in mitigation of coastal resource impacts.** Planning and project development should evaluate the societal and ecosystem service benefits of coastal resources at risk from sea-level rise or actions to prepare for sea-level rise. These benefits can include flood protection, carbon sequestration, water purification, tourism and recreation opportunities, and community character. Resource values can be quantified through restoration costs or various economic valuation models. Mitigation of resource impacts should include the best available information from research on and analytic tools for resource valuation.

D. MAXIMIZE AGENCY COORDINATION AND PUBLIC PARTICIPATION [Coastal Act Chapter 5; Sections 30006; 30320; 30339; 30500; 30503; 30711]

15. **Coordinate planning and regulatory decision making with other appropriate state, local, and federal agencies; support research and monitoring efforts.** Given the multitude of sea-level rise planning, research, and guidance efforts occurring in California, it is critical for agencies and organizations to share information, coordinate efforts, and collaborate where feasible to leverage existing work efforts and improve consistency. The Commission and Commission staff will continue to share information, coordinate its sea-level rise efforts with other relevant agencies and organizations,

support research and monitoring efforts, and also encourage local jurisdictions to both coordinate efforts regionally, and engage relevant stakeholders in the scoping, design, and implementation of adaptation actions. The Commission will also strive to provide the necessary training for Commissioners and Commission staff, and to support local governments, applicants, tribal groups, and other interested parties in the update of LCPs to address sea-level rise. Finally, it is critical that the Commission seek ongoing financial support for these efforts.

16. **Consider conducting vulnerability assessments and adaptation planning at the regional level**. Where feasible, local governments should coordinate vulnerability assessments and adaptation planning with other regional jurisdictions that face common threats from sea-level rise. A regional vulnerability assessment provides an opportunity to evaluate impacts that span multiple jurisdictions, assess and implement regional adaptation strategies, coordinate responses, and leverage research and planning funds. Regional planning is a crucial element to minimizing impacts to infrastructure and natural resources that span multiple jurisdiction boundaries.

17. **Provide for maximum public participation in planning and regulatory processes.** The Coastal Commission and Commission staff will continue to provide avenues for maximum public participation in planning and regulatory processes, and will continue to establish and/or expand non-traditional alliances (e.g. between/among public and private resource managers, tribal groups, scientists, decision-makers), share knowledge openly and actively, and regularly and clearly communicate to the public on the science as well as on a range of solutions to prepare for sea-level rise.

III. SEA-LEVEL RISE SCIENCE

This chapter includes:

A) Sea-level rise background information and a description of the best available science on the subject
B) Sea-level rise impacts to coastal areas
C) Implications of sea-level rise for coastal resources

It can serve as a source of scientific background information for users of this Guidance document.

A. Best Available Science on Sea-Level Rise

Scientists now widely agree that the climate is changing and that it has led to global increases in temperature and sea level. Global sea-level rise is driven by the expansion of ocean waters as they warm, the addition of freshwater to the ocean from melting land-based ice sheets and glaciers, melting sea ice, and from extractions in groundwater. In the past century, global mean sea level (MSL) has increased by 17 to 21 centimeters (7 to 8 inches) (IPCC, 2013). There are a number of methods for projecting future changes in global sea level, including using extrapolations from historic trends and observations, estimations from physical models, and combinations of observations and modeling, known as semi-empirical methods. For a detailed description of these methods, see Appendix A.

Scientists measure sea level change at the global and local scales. The *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (2012) report provides a set of four global sea-level rise scenarios ranging from 0.2 to 2.0 meters (8 inches to 6.6 feet) reflecting different amounts of future greenhouse gas emissions, ocean warming and ice sheet loss. The low and intermediate-low scenarios assume very significant reductions in greenhouse gas emissions, and limited changes in ocean warming and ice sheet loss. The intermediate-high scenario is based on the average of the high projections from semi-empirical models, which are based on the highest IPCC 4^{th} Assessment Report (AR4) (2007) emissions scenario (A1FI).[12] The highest scenario (2.0 meters) combines the IPCC projections with the maximum possible ice sheet melt that could occur by 2100. Given the recent studies that suggest that glacier and ice sheet loss could significantly contribute to rising sea-levels (e.g. Rahmstorf, 2007 and Vermeer and Rahmstorf, 2009) and evidence that current greenhouse gas emissions are tracking with intermediate AR4 IPCC scenarios (Rahmstorf et al., 2012), the low and intermediate-low scenarios likely under represent future sea-level rise. At the time of this report, these scenarios represent the best available science on global sea-level rise and are designed to be modified for

[12] The IPCC emissions scenarios make assumptions about future changes in population growth, future economic growth and the introduction of clean and efficient technology. The A1FI scenario assumes continued intensive use of fossil fuels, high economic growth, and low population growth that peaks mid-century. The B1 scenario assumes significant reduction in fossil fuel use, an increase in clean technologies, and the same low population growth that peaks mid-century. The A1F1 yields the highest CO_2 emissions by 2100 and the B1 scenario yields the lowest. For a complete description of these scenarios, see Appendix A, Section A.4.

local conditions throughout the United States. For California, the NRC 2012 report, described below, provides sea-level rise scenarios that have been refined for use at the regional level.

Best Available Sea-Level Rise Projections for California

Tide gauges and satellite observations show that in the past century, mean sea level in California has risen 20 centimeters (8 inches), keeping pace with global rise. In the past 15 years or so, mean sea level in California has remained relatively constant, and has been suppressed due to factors such as offshore winds and other oceanographic complexities. Bromirski et al. (2011 and 2012) postulate that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors cause a drop in sea level that may have cancelled out the sea rise that otherwise would be expected. As the Pacific Decadal Oscillation, wind, and other conditions shift, California sea level will continue rising, likely at an accelerated rate (NRC, 2012, Bromirski et al., 2011, 2012).

Over the coming decades, sea level is projected to increase along much of the California coast by up to 1.7 meters (5.5 feet) from 2000 to 2100, according to the 2012 National Research Council "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future" report (NRC, 2012).

In March 2013, the Ocean Protection Council adopted final Sea-Level Rise Guidance that established the NRC 2012 report as the best available science on sea-level rise for California (OPC, 2013).[13] Consistent with this guidance, the Coastal Commission will be using and recommends that local governments and applicants use the projections provided in the NRC 2012 report in all relevant local coastal planning and coastal development permitting decisions. The full range of sea-level rise projections is provided below in Table 3. Sea-level rise science is evolving and the Commission will periodically re-examine and update these projections as needed with the release of new scientific reports on sea-level rise. For now, however, the Commission staff recommends these figures as the best available projections of regional sea-level rise in California. The range of sea-level rise projections reflects uncertainties in future greenhouse gas emissions, future changes in the rate of ice sheet melt, and uncertainties related to the data. The low end of the projections is based on the lowest AR4 IPCC future CO_2 emissions scenario (B1) and the high end is based on the highest AR4 IPCC emissions scenario (A1FI) (2007). Again, given current greenhouse gas emission levels and projections of future ice sheet loss, the lowest sea-level rise projections likely under represent future sea-level rise (Rahmstorf et al., 2012).

[13] Visit http://www.opc.ca.gov/2009/12/climate-change/ for the State Sea Level Rise Guidance Document.

Table 3. NRC Sea-Level Rise Projections for California (NRC, 2012)

TIME PERIOD	NORTH OF CAPE MENDOCINO[14]	SOUTH OF CAPE MENDOCINO
2000 – 2030	-4 – +23 cm (-1.56 – 9 inches)	4 – 30 cm (1.56 – 11.76 inches)
2000 – 2050	-3 – + 48 cm (-1.2 – 18.84 inches)	12 – 61 cm (4.68 – 24 inches)
2000 – 2100	10 – 143 cm (3.6 – 56.28 inches)	42 – 167 (16.56 – 65.76 inches)

The NRC projections break the California coast into two regions – South of Cape Mendocino and North of Cape Mendocino. South of Cape Mendocino, much of the land is experiencing subsidence, which will augment the consequences of rising sea level. For much of the area north of Cape Mendocino, the consequences of rising sea level are being reduced by the vertical land uplift along much of the Cascadia Subduction Zone. However, much of this vertical uplift could change rapidly during the next large Cascadian earthquake. Areas north of Cape Mendocino could experience rapid subsidence of up to 2 meters (about 6 feet) when there is a large earthquake on this active subduction zone. In contrast to the vertical uplift occurring throughout the majority of the area north of Cape Mendocino, Humboldt Bay's North Spit is subsiding and experiencing the highest rate of sea-level rise in the state: a rate of 18.6 inches per century (NOAA, 2013).

Actual sea-level rise in a particular location along the coast will likely vary from these regional projections primarily due to changes in vertical land motion and ocean circulation. The projections also only provide estimated sea-level rise ranges through 2100, although sea level will continue to rise at an accelerating rate beyond the end of the century. As a result, it may be necessary for local governments, applicants, and staff to modify these projections to account for local conditions and specific time periods, using the steps provided in Appendix B.

B. Physical Impacts of Sea-Level Rise

Continued and accelerated sea-level rise will have widespread adverse consequences for California's coastal resources (See Figure 3), including increased inundation, flooding, coastal erosion, saltwater intrusion, and habitat loss. Absent any preparatory action, an increase in sea level may have serious implications for coastal property, infrastructure, and development; beaches, public access, and recreation areas; coastal habitats, and archeological and paleontological resources; fisheries, ports, and public works facilities; and some ground water aquifers.

[14] Since portions of Humboldt Bay are experiencing subsidence, and thus differ from the regional uplift conditions, the projections for north of Cape Mendocino may not be appropriate for use within parts of Humboldt Bay. See Appendix B for additional discussion about vertical land movement and relative sea-level rise.

Impacts from sea-level rise to the coastal zone include the following:

- **Flooding and inundation:** Low lying coastal areas may experience more frequent flooding (temporary wetting) or inundation (permanent wetting), and the inland extents of 100-year floods may increase. Riverine and coastal waters come together at river mouths, coastal lagoons, and estuaries, and higher water levels at the coast may cause water to back up and increase upstream flooding (Heberger et al., 2009). Drainage systems that outlet close to sea level could have similar problems, and inland areas may become flooded if outfall pipes back up with salt water. In addition, other climate change impacts such as increases in the amount of precipitation falling as rain rather than snow will add to river flooding in some areas.

- **Erosion:** Large sections of the California coast consist of oceanfront cliffs that are often highly susceptible to erosion. With higher sea levels, the amount of time that bluffs are pounded by waves at high tide would increase, causing greater erosion (NRC, 2012). This erosion could lead to landslides and loss of structural and geologic stability of bluff top property, the California Coastal Trail, Highway 1, and other roads and public infrastructure. In 2009, the Pacific Institute estimated that 41 square miles of coastal land between the California-Oregon border and Santa Barbara County could be lost due to increased erosion with 1.4 m of sea-level rise by the year 2100, putting at risk the 14,000 people who live in those areas. Increased erosion will not occur uniformly throughout the state and Mendocino and Humboldt Counties have the greatest areas projected to be lost by erosion. For example, dunes in Humboldt County could erode a distance of nearly 600 m (approximately 2000 feet) by 2100 (Heberger et al., 2009).

- **Changes in sediment supply and movement:** Sediment is important to coastal systems, for example, in forming beaches, mudflats, and as the substrate for wetlands. Sea-level rise will result in changes to sediment availability. Higher water levels and changing precipitation patterns could change erosion and deposition patterns. Losses of sediment could worsen beach erosion and possibly increase the need for beach nourishment projects (adding sand to a beach or other coastal area), as well as decrease the effectiveness and long-term viability of beach nourishment if sand is quickly washed away after being placed on a beach (Griggs, 2010). Sediment supplies in wetland areas will be important for long-term marsh survival. Higher water levels due to sea-level rise, however, may outpace the ability of wetlands to trap sediment and grow vertically (Titus, 1988; Van Dyke, 2012; Ranasinghe et al., 2012).

- **Saltwater intrusion:** An increase in sea level could cause saltwater to enter into ground water resources, or aquifers. Existing research suggests that rising sea level is likely to degrade fresh ground water resources in certain areas, but the degree of impact will vary greatly due to local hydrogeological conditions. Generally, the most vulnerable hydrogeological systems are unconfined aquifers along low-lying coasts, or aquifers that have already experienced overdraft and saline intrusion. In California, saline intrusion into groundwater resources is a problem in multiple areas, including but not limited to the Pajaro Valley (Hanson, 2003), Salinas Valley (Hanson et al., 2002a; MCWRA, 2012.), Oxnard Plain (Izbicki, 1996; Hanson et al., 2002b), and the heavily urbanized coastal plains of Los Angeles and Orange Counties (Ponti et al., 2007; Edwards and Evans, 2002; Nishikawa et al., 2009; Barlow and Reichard, 2010). Ground water sources for coastal agricultural lands may also be susceptible to saltwater intrusion. Additional research is needed to understand the site-specific consequences of sea-level rise and saltwater intrusion to these and other coastal aquifers in California.

C. Consequences of Sea-Level Rise for Coastal Resources and Development

Some of the consequences of sea-level rise are described below, along with the relevant Coastal Act policies:

- **Coastal development (Sections 30235, 30236, 30250, 30253):** Sea-level rise will increase the likelihood of property damage from flooding, inundation, or extreme waves, and will increase the number of people living in areas exposed to significant flooding. Increased erosion and loss or movement of beach sand will lead to an increase in the spatial extent of eroding bluffs and shorelines, and could increase instability of coastal structures and recreation areas. Levee systems could also experience damage and overtopping from an increase in water levels, extreme wave conditions, or a loss of wetlands, which buffer impacts from high water. The replacement value of property at risk from sea-level rise for the California coast is approximately $36.5 billion (in 2000 dollars, not including San Francisco Bay). The number of people living in areas exposed to flooding from a 100-year flood is estimated to increase by 67% with a 1.4 m increase in sea level (Heberger et al., 2009). According to Heberger et al. (2009), the greatest increases in the number of people vulnerable to flooding will occur in Los Angeles, San Diego, Ventura, Humboldt, and San Luis Obispo counties.

  Impacts to public infrastructure, ports, and industrial development include:

  - **Public infrastructure:** Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, and utility infrastructure such as potable water systems and electricity transfer systems are at risk of impaired function due to erosion, flooding, and inundation. Heberger et al. (2009) estimated that 7 wastewater treatment plants; 14 power plants, including one in Humboldt County and 13 in Southern California; and 250 miles of highways, 1500 miles of roads, and 110 miles of railways could be at risk from a 100-year flood with 1.4 meter rise in sea level (Heberger et al., 2009). Facilities and highways located on coastal bluffs subject to erosion will generally become more susceptible in the future. Sections of Highway 1 have already had to be replaced due to erosion, including areas in Monterey Bay, Half Moon Bay, Marin County, and Humboldt County, and the number of sections at risk in the future will likely increase.

  - **Ports (Sections 30703 – 30708):** Sea-level rise could cause a variety of impacts to ports, including flooding and inundation of port infrastructure and damage to piers and marina facilities from wave action and higher water levels. A possible benefit could be a decreased need for dredging. But, higher water levels could increase the difficulty for cargo handling facilities due to the higher vessel position (California Coastal Commission, 2001). Increased water heights could reduce bridge clearance, reducing the size of ships that can access ports or restricting movement of ships to low tides, and potentially increasing throughput times for cargo delivered to ports. Heberger et al. (2009) found that significant flooding from sea-level rise is possible at the Ports of Los Angeles and Long Beach. Given that these two ports handle 45-50% of the containers shipped into the United States, and 77% of goods that leave the state, sea-level rise could affect the efficiency of goods movement, and have serious economic implications for California and the nation (Heberger et al., 2009).

  - **Industrial development, refineries, and petrochemical facilities (Sections 30260-30266.5):** Sea-level rise could reduce areas available for siting or expansion of industrial development. Inundation of contaminated lands near industrial development could lead to problems with water quality and polluted runoff. Sea-level rise could lead to an increase in flooding damage of refineries or petrochemical facilities, and impacts from sea-level rise could be an issue when locating or expanding refineries or petrochemical facilities, or when mitigating any adverse environmental effects.

  - **Construction altering natural shoreline (Section 30235):** Sea-level rise may lead to an increase in demand for construction of shoreline protection for existing development, public access, and coastal dependent uses in danger of erosion. Shoreline protection devices alter natural shorelines and also generally have negative impacts on beaches, near-shore marine habitat, and scenic and visual qualities of coastal areas.

- **Coastal agriculture (Section 30241- 30243):** Sea-level rise could lead to an increase in flooding and inundation of low-lying agricultural land, saltwater intrusion into agricultural water supplies, and a decrease in the amount of freshwater available for agricultural uses. Flooding of agricultural lands can cause major impacts on local businesses, national food supplies, and the state's economy.

- **Public access and recreation (Sections 30210, 30211, 30213, 30220, 30221):** One of the highest priorities in the Coastal Act is the mandate to maximize public access to the coast. Sea-level rise could lead to a loss of public access and recreational opportunities due to permanent inundation, episodic flooding, or erosion of beaches, recreational areas, or trails. In areas where beaches cannot migrate inland due to development or existing landforms, beaches will become narrower or will disappear completely. Access and functionality of water-oriented activities may also be affected. For instance, sea-level rise, by increasing water levels and altering sediment patterns, could lead to a change in surfing conditions or affect the safety of harbors and marinas (Kornell, 2012).

- **Coastal habitats (Sections 30230, 30231, 30233, 30240):** Coastal habitat areas likely to be affected by sea-level rise include bluffs and cliffs, rocky intertidal areas, beaches, dunes, wetlands, estuaries, lagoons and tidal marshes, tidal flats, eelgrass beds, and tidally influenced streams and rivers. Impacts to wetlands, intertidal areas, beaches, and dunes include:

- **Beaches, dunes, and intertidal areas:** Inundation and increased erosion from sea-level rise could convert habitats from one type to another and generally reduce the amount of nearshore habitat, such as sandy beaches and rocky intertidal areas, available for species. Sea-level rise will cause landward migration of beaches over the long term, and could lead to a rapid increase in the retreat rate of dunes. Beaches with seawalls or other barriers will not be able to migrate landward and the sandy beach areas will gradually become inundated (NRC, 2012). A loss of beach and dune areas will have significant consequences for beach and adjacent inland ecosystems. Beaches and dunes provide critical habitat for species, act as buffers to interior agricultural lands and habitat during storms, and are essential for the persistence of dune habitats (CA Natural Resources Agency, 2009).

  In California, there are many endemic and endangered species that are dependent on bluffs and cliffs, dunes, sandy beaches, rocky intertidal areas, tidal marshes, and other coastal environments. For example, grunion need a sandy beach environment in order to survive, the California clapper rail is dependent on marshes and wetlands, and the black abalone requires rocky intertidal habitat. Nesting, nursery areas, and haul-out sites important for birds, fish, marine mammals and other animals could also disappear as sea levels rise (Funayama et al., 2012).

- **Wetlands:** Sea-level rise will lead to wetland habitat conversion and loss as the intertidal zone shifts inland. Of particular concern is the loss of saltwater marshes from sea-level rise, which have already decreased by about 90% from their historical levels in California (CA Natural Resources Agency, 2010). California's 550 square miles of critical coastal wetland habitat (Heberger et al., 2009, including wetlands in San Francisco Bay) will be converted to open water if they are not able to migrate inland due to natural or anthropogenic barriers. Although migration barriers are plentiful, inland migration of wetlands is possible in some areas. A 1.4 meter increase in sea level would flood 150 square miles of land immediately adjacent to wetlands, which could become future wetlands if that land remains undeveloped (Heberger et al., 2009). Loss or reduction of wetland habitat would impact many plant and animal species, including migratory birds that depend on these habitats as part of the Pacific Flyway. Species that are salt-tolerant may have an advantage as sea-level rise occurs, while species that have narrow salinity and temperature tolerances may have difficulty adapting.

- **Water quality (Section 30231):** Coastal water quality could decrease due to inundation of toxic soils and an increase in nonpoint source pollution from flooding. Sea-level rise could also lead to declines in coastal water quality in several other ways. First, rising seas could impact wastewater facility infrastructure near the coast. In addition to damaging equipment and blocking discharge from coastal outfall structures, floods could force facilities to release untreated wastewater, threatening nearby water quality (Heberger et. al., 2009). Second, sea-level rise could lead to salt water intrusion into valuable ground water aquifers, potentially rendering some existing wells unusable and decreasing the total ground water supply in coastal areas. The extent of salt water intrusion will likely vary based upon local hydrological conditions, with the worst impacts occurring in unconfined aquifers along low-lying coasts that have already experienced overdraft and saline intrusion. This change could force affected communities to turn to more costly water sources such as surface water transfers or desalination. Finally, loss of wetlands could decrease water quality since wetlands improve water quality by slowing and filtering water that flows through them.

- **Biological productivity of coastal waters (Section 30230, 30231):** Sea-level rise could affect biological productivity of coastal waters by changing the types of habitats that are available, which would alter species compositions, and could potentially affect the entire coastal food chain. Changes in water quality can have differing impacts on biological productivity. For instance, decreased water quality due to increased nutrient pollution has been found to increase biological productivity at the base of the food chain to undesirable levels, and has been linked to harmful algal blooms (Caldwell et al., 2013; Kudela, Seeyave, and Cochlan, 2010; Ryan, McManus, and Sullivan, 2010).

- **Archeological and paleontological resources (Section 30244):** Archeological or paleontological resources could be put at risk by inundation, flooding, or by an increase in erosion due to sea-level rise. Areas of traditional cultural significance to California Native American tribes, including villages, religious and ceremonial locations, middens, burial sites, and other areas, could be at risk from sea-level rise. For example, the Santa Barbara Channel area has thousands of archaeological sites dating over 13,000 years that are at risk of being destroyed or altered from small amounts of sea-level rise (Reeder et al., 2010).

For a summary of some of the sea-level rise impacts and potential consequences for the coast, see Figure 3. Many of these are impacts that coastal managers already deal with on a regular basis, and strategies already exist for minimizing impacts from flooding, erosion, saltwater intrusion, and changing sediment patterns. Preparing for sea-level rise involves integrating future projections of sea levels into existing hazard analyses, siting, design, and construction processes, and ecosystem management practices.

Sea-Level Rise Impacts and Consequences

Drivers of Global SLR

- Expansion of ocean water as temperature increases
- Addition of freshwater to the ocean from melting glaciers and ice sheets
- Addition of freshwater to the ocean from groundwater extraction, use, and discharge

Drivers of Local/Regional SLR Variability

- Vertical land movement
- Oceanographic phenomena including El Nino Southern Oscillation (ENSO) and

Physical Impacts of SLR

- Inundation (permanent wetting)
- Flooding (temporary wetting)
- Increased erosion and bluff collapse
- Increased tidal prism
- Increased wave heights and force
- Increased saltwater intrusion
- Change in sediment movement patterns

Summary of Consequences of SLR for Coastal Resources & Development

Public Access & Recreation: Loss of beach areas where beaches cannot migrate inland due to development; inaccessibility of public accessways and recreation sites due to flooding and erosion.

Coastal Habitats: Transformation of habitats as intertidal zone shifts inland; loss of wetlands and other habitats where areas cannot migrate up or inland due to inland barriers such as coastal development.

Coastal Agriculture: Increase in flooding and inundation of low-lying agricultural lands; saltwater intrusion into agricultural water supplies; potential decrease in amount of freshwater available for agricultural uses, or inability of wetlands to keep pace vertically with rising water levels.

Cultural Resources: Archeological and paleontological sites, including many Native American villages, religious and ceremonial locations, burial sites, and other areas could be at risk from sea-level rise.

Public infrastructure: Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, potable water systems, and electricity transfer systems are at risk of inundation and flooding, and impaired function. Infrastructure located on eroding bluffs is also subject to increased geologic hazards.

Ports & Marinas: Possible decrease in need for dredging; damage to piers and marina facilities from greater uplift forces and higher water levels; potential difference in heights between ships, cargo handling facilities and drydock/ ship repair facilities.

Coastal Development: Greater likelihood of tidal damage, flooding, inundation, and extreme waves, which could lead to loss of property or physical injury; instability from increased erosion and loss/movement of beach sand; increased areas exposed to a 100-year flood.

Figure 3. Summary of Sea-Level Rise Impacts and Consequences

IV. ADDRESSING SEA-LEVEL RISE IN LOCAL COASTAL PROGRAMS

The Coastal Act requires that the 76 cities and 15 counties in coastal California prepare Local Coastal Programs (LCPs) to govern land use and development in the coastal zone above the mean high tide. LCPs become effective only after the Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act.

LCPs contain the ground rules for future development and protection of resources in the coastal zone. Each LCP includes a Land Use Plan (LUP) and an Implementation Plan (IP). The LUP specifies the kinds, locations, and intensity of uses, and contains a required Public Access Component to ensure maximum public access to coastal and public recreation is provided. An IP includes measures to implement the plan, such as zoning ordinances. LCPs are prepared by local governments and submitted to the Coastal Commission for review for consistency with Coastal Act requirements.[15]

Once a LCP's certification becomes effective, the local government becomes responsible for reviewing most Coastal Development Permit (CDP) applications. However, the Commission retains some continuing permit authority over some lands (for example, over tidelands, submerged lands, and public trust lands) and authority to act on appeals from certain categories of local coastal permit decisions.

LCPs are essential to fully implementing sea-level rise adaptation efforts. As many of the LCPs were certified in the 1980s and 1990s, it is important that future amendments of the LCPs consider sea-level rise and adaptation planning at the project and community level, as appropriate. The California Climate Adaptation Strategy (2009) specifically identifies LCPs as a mechanism for adaptation planning along the California coast.

Steps for Addressing Sea-Level Rise in Local Coastal Programs and other Plans

The steps for addressing sea-level rise in LCPs are similar to the standard steps of a long-range planning process and should be familiar. The Commission recommends the following six steps to address sea-level rise as part of the development of a LCP, LCP Amendment, or other plan.[16] These steps can be modified and adapted to fit the needs of individual planning efforts and communities and to address the specific coastal resource and development issues of a community, such as dealing with bluff erosion or providing for effective redevelopment, infill, and concentration of development in already developed areas. Local government planners should consult with Commission staff during each of these steps. The steps are illustrated in Figure 4 and described below.

[15] In addition there are other areas of the coast where other plans may be certified by the Commission, including Port Master Plans for ports governed by Chapter 8 of the Coastal Act, and Long Range Development Plans for state universities or colleges and Public Works Plans. Following certification by the Commission, some permitting is delegated pursuant to the Coastal Act provisions governing the specific type of Plan.
[16] The guidance uses the term 'LCP process' to refer to the LCP process as well as other planning processes, including Long Range Development Plans, Public Works Plans, Port Master Plans, etc.

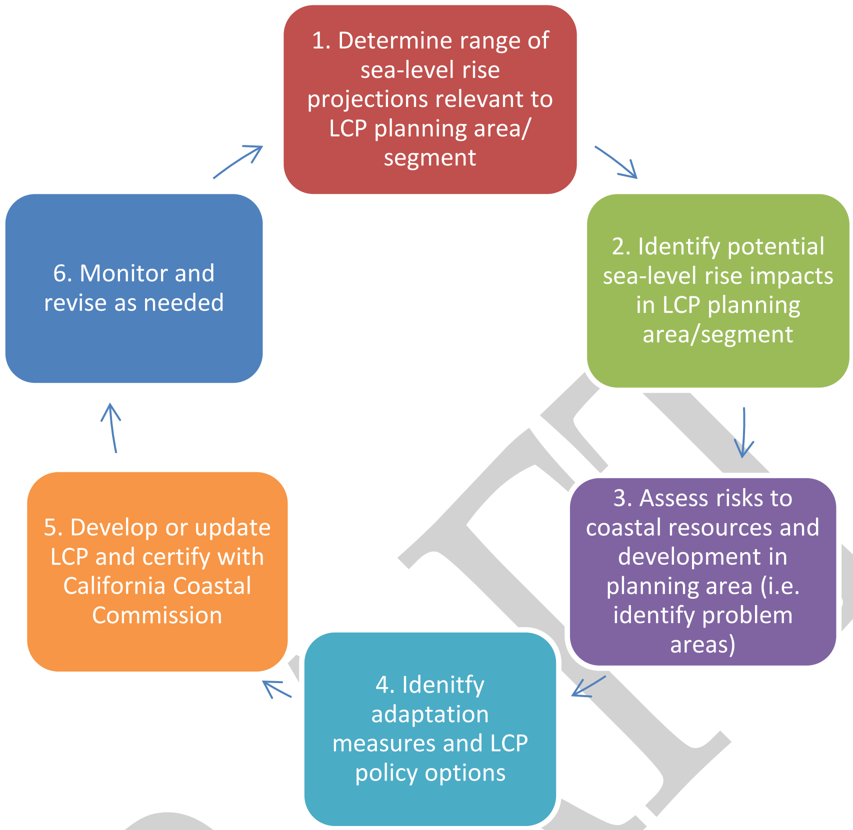


Figure 4. Sea-Level Rise Adaptation Planning Process for new and updated Local Coastal Programs

Step 1 - Determine range of sea-level rise projections relevant to LCP planning area or segments.

Follow these steps to determine the locally relevant sea-level rise projections to use in the rest of the sea-level rise adaptation planning process:

- **Determine planning horizons of concern:** The NRC report for California uses the time periods of 2030, 2050, and 2100 to project future sea levels. These ranges may be used, or local governments can identify other relevant planning horizons for their plans and development scenarios, as long as the projections for those time frames are based on the best available and relevant scientific projections.

- **Determine projections from best available science:** Using the NRC report or other comparable study, determine the range of sea-level rise for the planning horizons of concern. If those time periods extend past 2100, extrapolate from the NRC projections (See Appendix B for more details on this step). The LCP should include a policy to use the best available science about sea-level rise. Also, local governments may consider including higher scenarios (such as a 2 meter (6.6 foot) scenario[17]) where severe impacts to Coastal Act resources could occur from sea-level rise.

- **For parts of the Humboldt Bay region and Eel River Estuary, modify projections for vertical land motion:**[18] For project locations in the vicinity of Humboldt Bay and the Eel River Estuary, the regional NRC sea-level rise projections will need to be modified to adjust for localized vertical land motion and this is discussed further in Appendix B. Adjustments for vertical land motion are not recommended for other locations.[19] However, if sea-level rise projections are modified for areas other than the Humboldt Bay region, at least one scenario for the analysis of impacts should use the high value from the unmodified NRC projections.

Expected outcomes from step #1: *Upon completing this step, a range of locally-relevant sea-level rise projections for the time periods of concern should be established.*

Step 2 - Identify potential physical sea-level rise impacts in LCP planning area/segment.

The next step is to identify the physical hazards and impacts (referred to comprehensively as sea-level rise impacts) associated with current and future sea level. Sea-level rise impacts may include inundation, flooding, wave impacts, erosion, and saltwater intrusion. Consider how sea-level rise could interact with or exacerbate the following local water conditions: seasonal erosion, tidal range, surge, increased water levels from atmospheric forcing due to an El Niño Southern Oscillation (ENSO) or Pacific Decadal Oscillation (PDO), and waves, usually from a 100-year storm event (i.e. an eroded shoreline condition), in addition to the local sea-level rise projections. For a methodology to determine local water conditions, see Appendix B.

Questions to help identify future hazards and sea-level rise impacts include:

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[17] The Global Sea Level Rise Scenarios for the United States National Climate Assessment 2012 establishes 2 meter (6.6 feet) as the highest global sea-level rise scenario for 2100.

[18] Vertical land motion describes the subsidence or uplift of land and is caused by different processes, including tectonic activity, sediment compaction, groundwater or other fluid withdrawal and recharge, and glacial isostatic adjustment. Land North of Cape Mendocino is generally found to be rising at a rate of 1.5- 3.0mm/year, with the exception of parts of Humboldt Bay and the Eel River Estuary, which is subsiding. Land South of Cape Mendocino is subsiding at a rate of ~1mm/year, with variation in areas South of Cape Mendocino from -3.7 mm to 0.6 mm/year (NRC, 2012, pg. 78).

[19] A three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City. The OPC-SAT subcommittee stated, "We do not believe that there is enough certainty in the sea-level rise projections nor is there a strong scientific rationale for specifying specific sea-level rise values at individual locations along California's coastline" (OPC, 2013, pg. 10).

- What are the existing flood, erosion, saltwater intrusion, water table, and coastal water quality conditions relevant to the planning area?
- What is the projected change in conditions due to locally appropriate sea-level rise projections and planning horizons of concern?

As part of the LCP, document in the Land Use Plan the current and future hazard areas in maps, GIS products, graphics, tables, charts, figures, descriptions, or other means. This process should be repeated for each planning horizon defined in Step 1. Evaluation of current and future conditions includes assessment of the following topics. Appendix B includes methodologies for these analyses.

- Current and future submerged and intertidal lands based on tidal elevations.
- Current and future cliff and beach erosion rates. For future erosion rates, modify historic cliff and dune erosion rates (see, for example, work by the Pacific Institute), to account for the influence of sea-level rise. If possible, modify long-term beach erosion rates to account for changes in sediment supply or changing transport conditions.
- Current and future flood zones and wave impacts from high tide, a 100-year storm event, elevated water level due to El Niño, etc., and seasonally eroded beach and long-term beach erosion; and from extreme events such as a greater than 100-year recurrence interval storm, a series of large storms, or a tsunami. For future flood zones, combine with the high range of locally appropriate sea-level rise projections.
- Current and future saltwater intrusion areas.
- Current and potential future coastal water pollution issues due to inundation of toxic soils, rising water tables, and increases in nonpoint source pollution.

In preparing an updated Land Use Plan, use existing models, tools, reports, historic records and other material to develop or double check the identified hazard areas. Modify the current and future hazard areas on a five to ten year basis to update planning horizons of concern and allow the incorporation of new sea-level rise science, monitoring results, and information on coastal conditions.

Expected outcomes from step #2: *Upon completing this step, the potential current and future impacts should be identified based on sea-level rise projections to the planning area from sea-level rise hazards. Maps, GIS layers, graphics, figures, charts, tables, descriptions, or another system should be developed to communicate the impacts of current and future hazards.*

Resources for Sea-Level Rise Mapping

Table 4 includes a list of sea-level rise mapping tools. See Appendix B for additional information on determining hazard impacts and tools for mapping sea-level rise.

Table 4. Sea-Level Rise Mapping Tools

Tools	**Specifics of Information**	**Source**
Statewide		
NOAA Digital Coast Sea-Level Rise Viewer	Displays potential future sea levels with a slider bar. Communicates spatial uncertainty of mapped sea-level rise, overlays social and economic data onto sea-level rise maps, and models potential marsh migration due to sea-level rise. Maps do not include any influence of beach or dune erosion.	http://www.csc.noaa.gov/digitalcoast/tools/slrviewer
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 1.4 meter rise in sea level and a 100-year flood event. Maps do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
Pacific Institute Sea-Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlayed on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea-level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report "The Impacts of Sea-Level Rise on the California Coast" visit: http://www.pacinst.org/reports/sea_level_rise/report.pdf
Sea-Level Rise Affecting Marshes Model (SLAMM)	Simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea-level rise. Map distributions of wetlands are predicted under conditions of accelerated sea-level rise, and results are summarized in tabular and graphical form.	http://www.warrenpinnacle.com/prof/SLAMM

Coastal Storm Modeling System (CoSMoS)	A numerical modeling system to predict coastal flooding due to both sea-level rise and storms driven by climate change. Used in the Our Coast Our Future and for a Southern California Pilot Project. Modeling of entire Southern California Bight is expected to occur by 2014-2015, if funding is secured.	http://data.prbo.org/apps/ocof/uploads/documents/CoSMoSFAQ2013.pdf
South Coast		
Coastal Resilience Ventura	A partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change. The primary goals of Coastal Resilience Ventura are assessing the vulnerabilities of human and natural resources, and identifying solutions that help nature help people.	http://coastalresilience.org/geographies/ventura-county
North Central Coast		
Our Coast Our Future (Map is available for Bodega Head to Half Moon Bay)	Provides online maps and tools to help understand, visualize, and anticipate vulnerabilities to sea-level rise and storms, including seamless Digital Elevation Model (DEM) at 2 meter horizontal resolution; 25 cm increment sea-level rise projections between 0 - 2 meters with a 5 meter extreme; storm scenarios using the Coastal Storm Modeling System (CoSMoS); and interactive maps overlaying infrastructure and ecosystem vulnerabilities. Learn more at www.prbo.org/ocof.	http://data.prbo.org/apps/ocof/index.php?page=ocof-map
Humboldt Bay Shoreline Inventory, Mapping, and Sea-Level Rise Vulnerability Assessment (Aldaron Laird, 2012)	This project is the first comprehensive inventory and mapping of Humboldt Bay's existing shoreline attributes: structure, cover, and elevation. An analysis was prepared of existing shoreline vulnerabilities under the current tidal regime. An existing shoreline vulnerability assessment to sea-level rise was also prepared to identify land uses and infrastructure, potentially at risk, if no mitigation measures are implemented.	http://humboldtbay.org/sites/humboldtbay.org/files/Humboldt%20Bay%20-%20Mapping%20and%20SLR%20Vulnerability%20Assessment-A.Laird.pdf

Step 3 - Assess potential risks from sea-level rise to coastal resources and development in LCP planning area/segment.

After sea-level rise impacts are identified and mapped in step 2 above, the next step is to determine whether sea-level rise poses any risks, or potential problems, for coastal resources and development in the LCP planning area. Next, assess whether the LCP planning area's current and planned land uses are feasible given those impacts, and if those land uses should be revised in response. This step requires an understanding of several characteristics of the coastal resources and development typically found within various land use types. (Much of this information can be produced in a vulnerability assessment, an analysis that is commonly conducted in the planning and climate change adaptation field. See Appendix D for a list of recent sea-level rise vulnerability assessments.)

Consider coastal development and resources, including but not limited to:

- Existing and planned development
- Coastal-dependent uses such as harbors and wharfs
- Critical infrastructure such as wastewater treatment plants, transportation infrastructure, and electricity and other energy transmission infrastructure
- Public accessways, beaches and other recreation areas, and the California Coastal Trail
- Coastal Highway 1
- Wetlands, ESHA, and other coastal habitats and sensitive species
- Ports, marinas, harbors, commercial and recreational fishing areas and facilities
- Agricultural areas
- Cultural sites and resources archeological or paleontological resources
- Visitor-serving and coastal-dependent development and uses

Conduct the following steps for each planning horizon (i.e. 2030, 2050, and 2100, or other planning horizons):

1. For the planning horizon of interest, determine what development and coastal resources may be subjected to the sea-level rise impacts expected for that time period. Map the coastal resources that lie within the sea-level rise impact areas for the given time period. (Remember to address the wide range of resources listed above, including both natural resources and development.)

2. Determine if sea-level rise impacts are a problem for each resource, and if so, to what degree the resource will be impacted. To accomplish this step, consider a wide range of characteristics of each resource, including:

    a. **Exposure.** Will sea-level rise impacts affect the resource/development at all?
        i. Are coastal resources and community assets exposed to sea-level rise impacts?
        ii. Is the resource already exposed to hazards such as waves, flooding, erosion, or saltwater intrusion? If it is, will sea-level rise increase hazard exposure?

b. **Sensitivity.** If resources are exposed, to what degree will coastal resources/development be affected by sea-level rise impacts? A simple way to think about this concept is to consider how *delicate* the resource or development is in regard to sea-level rise impacts.
   i. How quickly will the resource respond to the impact from sea-level rise?
   ii. Will the resource/development be harmed if environmental conditions change just a small amount? What are the physical characteristics of resource/asset? (E.g. geology, soil characteristics, hydrology, coastal geomorphology, topography, bathymetry, land cover, land use, etc.). Do any of those characteristics make the resource especially sensitive?
   iii. Are there amounts of sea-level rise that cause sensitivity to sea-level rise to increase?

c. **Adaptive Capacity.** How easily can the resource successfully adapt to sea-level rise impacts?
   i. How well can the resource/development accommodate changes in sea level?
   ii. How easily can development be modified to cope with flooding or inundation, or erosion? Can structures be elevated or relocated?
   iii. Is rate of change faster than the ability of the resource/development to adapt?
   iv. Are there adaptation efforts already underway? Are there any factors that limit the success of adaptation efforts?
   v. Do wetlands and other coastal habitats have room to migrate inland? What is the overall health of existing wetlands and coastal habitats? Are there many non-climate stressors that could impair ability to adapt to sea-level rise?
   vi. What are the options to protect, redesign (e.g., elevate), or relocate inland any existing public accessways, recreational beaches, and segments of the Coastal Trail to cope with rising sea levels? Is lateral access compromised with sea-level rise?

d. **Consequences.** When sea-level rise has impact(s) upon a resource, what are the economic, ecological, social, cultural, and legal consequences?
   i. How severely could the impact affect each resource? What is the scale of the impact?
   ii. Are there cumulative consequences?
   iii. Are there ripple effects, or secondary consequences to consider?
   iv. Will human responses cause further adverse impacts?

e. **Land Use Planning Options and Constraints.** Given the location of sea-level rise impacts and the resources currently located in those areas, should the kinds and intensities of land uses be changed to minimize hazards and protect coastal resources?

i. What conditions does the land use type, development, or resource require to either exist or fulfill its intended purpose?
ii. Is it a coastal dependent use? What is its ideal proximity to the coast?
iii. For development, what is its economic lifespan? Is it economically feasible to locate it in a sea-level rise impact area for a certain period of time before it is removed or relocated?
iv. For a natural resource or habitat, what conditions does it require to persist?
v. Where should resources/development ideally be located after sea-level rise causes environmental conditions to shift?

After going through the questions listed above, synthesize the information and determine where sea-level rise impacts currently pose problems for coastal resources and how urgent those problems are. Create maps illustrating the location and extent of vulnerable land uses, such as wastewater infrastructure or State Highway 1. This information can also be summarized in narrative form. This analysis should reveal resources likely to be impacted by sea-level rise at various time steps in the future, and thus the issues that need to be resolved in the LCP planning process.

Remember that these assessments are not static; existing risks will change and new risks will arise with changes in a community, the emergence of new threats, and the implementation of adaptation actions. For this reason, the analysis should be updated as needed to reflect changes in sea-level rise projections, changes in land use patterns, or new threats.

Expected outcomes from step #3*: Descriptions of the characteristics that influence risk, including exposure, sensitivity, and adaptive capacity of each coastal resource to sea-level rise impacts, along with the expected consequences of those impacts for the resource and broader community. Maps of resources and/or land uses at risk.*

Example for Step 3

Consider a hypothetical planning area that hosts multiple coastal resources, including a coastal wetland, bluff-top residential development, and a wastewater treatment facility. After steps 1 and 2, you discover that portions of the planning area are subject to current and future sea-level rise impacts.

Step 3.1

Map the coastal resources (in this case the wetland, development, and wastewater treatment facility) for the range of time periods and sea-level rise projections.

Step 3.2

a. **<u>Exposure</u>**

- *Wetland:* The wetland is highly exposed to flooding and inundation from sea-level rise. By 2030, portions of the wetland will experience periodic flooding during high tides. By 2050, a portion of the wetland will become inundated and converted to open water, and by 2100 the entire area will be converted to open water. The wetland will be completely lost by this time period if it is not able to move inland.
- *Bluff-top Residential Development:* Houses in the residential development are not exposed to sea-level rise impacts in 2030. However, a high rate of erosion will put front-line houses in danger of collapse by 2050, and the entire development will be lost by 2100.
- *Wastewater Treatment Facility:* Given that the wastewater treatment plant is set back somewhat from the water, it will not be exposed to impacts from sea-level rise until 2050. By 2050, however, portions of the infrastructure will be exposed to impacts from elevated water levels due to 100-year storm events and El Nino occurrences. By 2100, significant portions of the facility will be exposed to flooding as the surrounding area is eroded and inundated.

b. **<u>Sensitivity</u>**

- *Wetland:* The wetland has high sensitivity to changes in sea level because it's functioning is highly dependent on local physical parameters such as water flow, tidal fluctuation, sediment supply, and water quality. Thus, although it currently has good sediment supply, good water quality, and a number of other characteristics, small changes in sea-level rise by 2050 may alter the function of the wetland. In addition, there are concerns that beyond 2050 the wetland will not be able to keep up with accelerated sea-level rise, thus increasing sensitivity to further changes in sea level.

Example for Step 3, cont'd

- *Bluff-top Residential Development:* The residential development has moderate to high sensitivity to longer-term sea-level rise changes. By 2050, the front-line houses will no longer be safe enough to serve as residences. Moreover, infrastructure such as roads, sewage systems, and power networks may be damaged as the bluff-face erodes.

- *Wastewater Treatment Facility:* The facility is moderately sensitive to sea-level rise. Flooding and erosion from sea-level rise could cause damage of the facility, pumps and other equipment, but it is likely that the facility is built to withstand a high degree of storm and related impacts.

c. **<u>Adaptive Capacity</u>**

- *Wetland:* The wetland has a moderate-high adaptive capacity because it has the ability to both accumulate sediment and grow upwards, and, given that the land upland of the wetland is preserved as open space, it can migrate inland. However, by 2050, a part or all of the wetland could be converted to open water if the wetland is not able to migrate inland or accumulate sediment at a rate that keeps pace with sea-level rise. Additionally, adaptive capacity may be reduced if pollution increases (for example as a result of damage to adjacent development) and disrupts the normal functioning of the wetland.

- *Bluff-top Residential Development:* The residential development has a moderate adaptive capacity. As houses become threatened over time, a scenario of managed retreat would allow houses to be relocated to safer areas. In addition, a protective structure such as a seawall would minimize threats due to erosion.

- *Wastewater Treatment Facility:* The wastewater treatment facility has a very low adaptive capacity. It is large and has expensive infrastructure so it cannot be elevated, and relocation is costly and difficult. In order to be protected in its current location, new structures will need to be built.

d. **<u>Consequences</u>**

- *Wetland:* The wetland is at moderate risk due to its high adaptive capacity. In the short term, the wetland will likely continue to function at normal levels. However, if it eventually can't keep up with sea-level rise or if there are barriers to migration, loss of the habitat will result in a loss of important ecosystem services. Essential habitat for fish and bird species will be lost, and the loss of the wetland buffer may exacerbate erosion and flooding to surrounding areas.

- *Bluff-top Residential Development:* The housing development has medium to high risk through 2100. The option to either relocate houses or protect them with a seawall means that they could continue to exist. Importantly, a system of managed retreat will allow for the continued existence of the fronting beach whereas the construction of a seawall will result in the loss of the beach.

Example for Step 3, cont'd

- *Wastewater Treatment Facility:* Given its low adaptive capacity and high sensitivity to higher levels of sea-level rise, the wastewater treatment facility is at high risk. Loss or damage to the facility could result in serious social, economic, and environmental consequences. Flooding of the facility and surrounding areas will cause damage to infrastructure and loss of facility function. This could lead to discharge of untreated sewage, which would have adverse impacts to water quality and could impair the health of nearshore ecosystems. Sea-level rise could also cause outflow pipes to back up with seawater, leading to inland flooding and additional water quality problems. However, efforts to protect the structure may have unintended consequences including loss of surrounding habitat areas.

e. **Land Use Planning Options and Constraints**

- *Wetland:* The high adaptive capacity of the wetland means that protecting this resource may only mean ensuring that there is space available for it to move into. Land use policies designed to protect areas inland of the current wetland area will be necessary.
- *Bluff-top Residential Development:* The area in question will eventually become incompatible with the current use. Development will not begin to be exposed to sea-level rise impacts until 2050, but it is important to start planning now about how best to protect the houses. Managed retreat will necessitate identifying feasible locations into which houses could be moved or a plan to abandon and remove houses.
- *Wastewater Treatment Facility:* The biggest question in this scenario is the wastewater treatment facility. It should be determined how likely it is that the facility will be able to be protected throughout the rest of its economic lifespan under even the highest sea-level rise scenarios. It may be that the wastewater treatment facility becomes an incompatible use under future conditions. If so, plans should be made to relocate at-risk portions of the facility, as feasible, or to phase out the facility.

Decisions about how to address various challenges presented by sea-level rise will require prioritizing the different resources based on the goals of the community and the various characteristics of each resource. An understanding of the exposure, sensitivity, adaptive capacity, consequences, and requirements for the particular resources and scenarios will need to be kept in mind as managers move into Step 4 to identify possible adaptation strategies.

Step 4 - Identify adaptation measures to minimize risks.

Whether as part of a new LCP or as part of an amendment to update a certified LCP, coastal managers should develop strategies and new or revised land use designations, policies, standards, or ordinances to address sea-level rise impacts.

A LCP as certified by the Commission will already have included land uses policies, standards, and ordinances to implement Chapter 3 policies related to hazard avoidance and mitigation, and may already contain significant hazard policies that may need to be revised to reflect new information and new techniques. The LCP should be evaluated to identify the land use designations policies or ordinances that may need to be amended. A LCP update may need to include a variety of adaptation measures depending on the nature and location of the vulnerability.

The following sections address measures that local governments should consider in their LCPs, organized by category of coastal resource. For each issue area, there is a description of potential impacts that could occur due to sea-level rise, a list of adaptation tools or actions to minimize impacts, and a description of how to update the LCP. To skip to a topic, click on the links below.

The following sections present measures that local governments should consider including in their LCPs, organized by category of coastal resource. Additional guidance for developing or updating a LCP can be found in Appendix C and Appendix D and should be consulted as part of any update or new LCP process.

4.1 Planning and Locating New Development

Suggested Changes to the LCP:
Certified LCPs should address the kinds, locations, and intensity of uses allowed. The types and locations of uses may need to be revised given increases in coastal hazards due to sea-level rise. For example, land adjacent to wetlands may need to be rezoned to restrict development in order to allow wetlands to migrate inland over time. Also, development policies may need to be updated to reflect new limits on the capacity of public works facilities, such as limiting new development that relies on groundwater resources susceptible to saltwater intrusion. As part of the update, designate sufficient land for priority uses under the Coastal Act to ensure that priority uses will continue to be accommodated over time as sea-level rise occurs.

Potential Impacts to Development:
- Development in coastal areas is at increased risk to coastal hazards.
- Property damage due to hazards can impair coastal water quality, sensitive habitat, public access, and other coastal resources.

Actions to Minimize Impacts:
- Limit new development in hazard areas.
- Convert areas vulnerable to sea-level rise to conservation areas or open space.
- Add additional development controls in areas subject to risks from sea-level rise.
- Cluster development away from hazard areas.

What should updated development standards include?

✓ **Update inventory and maps:** The LCP update should include an updated inventory and map of all land uses, clearly showing areas vulnerable to sea-level rise.

✓ **Update land use designations and zoning ordinances:** For any areas that become hazardous due to sea-level rise, establish hazard zones or overlays and update land uses and zoning requirements to minimize risks from sea-level rise.

✓ **Convert vulnerable areas to conservation or open space sites:** Update land use designations to establish conservation, open space, or recreation uses in areas where sea-level rise could be an issue. Allow and encourage retirement or transfer of development rights on private property that is subject to sea-level rise.

✓ **Limit first floor habitable space:** Where applicable, revise residential building standards to limit first floor habitable space in areas likely subject to flood/wave action.

✓ **Limit second units:** In areas subject to erosion, flood, or wave hazards add policies to limit the addition of second units to areas where future protection is not needed and there are no coastal resource impacts, including any future risks due to sea-level rise over the entire life of the primary structure.

✓ **Limit subdivisions in areas vulnerable to sea-level rise:** Prohibit any new land divisions, including subdivisions, lot splits, lot line adjustments, and certificates of compliance that create new beachfront or blufftop lots unless lots can meet specific criteria that ensure they are not exposed to hazards or pose any risks to protection of coastal resources.

- ✓ **Consider a shorter development life for constrained lots:** When a lot is not large enough to provide a safe building area for the proposed life of the development without reliance upon protection or impacts to coastal resources, a shorter proposed life could allow development to occur for the short time period that the site can safely support such a use.

- ✓ **Limit or prohibit use of bluff retention or shoreline protection for new development:** LCPs should have policies that require new development to be safe from bluff retreat, waves, or flood hazards without the use of any shoreline protective device. This policy preserves the ability of the shoreline to retreat naturally with changing conditions, which is especially important given projected changes from sea-level rise. LCPs should also require new development in potentially hazardous locations to include a waiver of rights to future shoreline protection.

- ✓ **Ensure that current and future risks are assumed by the property owner:** New development should be undertaken in such a way that the consequences from development in high-hazard areas will not be passed on to public or coastal resources. Establish standards that ensure that current and future risks are assumed by the property owner.

- ✓ **Limit development near vulnerable water supplies:** Limit new development in areas dependent on water supplies susceptible to saltwater intrusion.

- ✓ **Restrict development of new wells:** Require water wells to be sited away from areas where saltwater intrusion could occur. Establish standards for use of sensitive aquifers to reduce risks of saltwater intrusion.

- ✓ **Cluster development:** Concentrate development away from hazardous areas. Update any existing policies that cluster development to reflect additional hazard zones due to sea-level rise.

- ✓ **Redevelopment restrictions:** Limit expansion of non-conforming or other land uses in hazardous areas. For example, require projects that involve significant exterior and/or interior alterations of non-conforming structures to bring the entire structure into conformity with current requirements regarding avoidance and minimization of hazards. Significant alterations can be defined as:
    - Replacement of 50% or more of an existing structure, including but not limited to, demolition of 50% or more of the exterior walls or major structural components, or a 50% increase in floor area.
    - Demolition, renovation or replacement of less than 50% of an existing structure where the proposed remodel would result in cumulative alterations exceeding 50% or more of the existing structure from the date of certification of the LUP.

4.2 Hazards and Shoreline/Bluff Development

Suggested Changes to the LCP:
The hazards section of the LCP will likely need to be updated to ensure hazards from sea-level rise are considered in hazard analyses, siting and design of new development, and to establish programs and policies to address existing development located in high-risk areas. The responses to address hazards due to sea-level rise should have the least impact on coastal resources.

Potential Hazard Impacts:
- Coastal resource impacts due to property damage from flooding and erosion.
- Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, potable water systems, and electricity transfer systems are at risk of inundation, flooding, or erosion impacts.
- Increase in number of people and structures exposed to flooding from a 100-year flood event.
- Increase in instability of structures and recreation areas exposed to erosion.
- Overtopping or damage of levees.

Actions to Minimize Impacts:
- Limit development in hazard areas.
- Add additional development controls in areas subject to risks from sea-level rise. These may expand the existing areas where flood and erosion policies apply.
- Site and design development to avoid or minimize hazards due to sea-level rise.
- Include sea-level rise in tsunami wave runup calculations.

What should the updated component include?

✓ **Update land use designations/ zoning:** Update land use designations to limit development within areas subject to hazards from sea-level rise and to encourage removal of threatened development and transfer of development rights away from such areas.

✓ **Update development standards:** Establish development standards for properties within sea-level rise zones, such as updated flood protection measures to avoid and minimize flood risks.

✓ **Applications for new development in areas where sea-level rise may be a concern should include a site-specific evaluation of sea-level rise:** Update policies, ordinances, and permit application requirements to include an analysis of coastal hazards due to sea-level rise over the full projected life of the structure. Analyses should be conducted by a certified civil engineer with expertise in coastal processes.

✓ **Incorporate sea-level rise into calculations of the Geologic Setback Line:** Update geotechnical report requirements for establishing the Geologic Setback Line (bluff setback) to include consideration of bluff retreat due to sea-level rise, in addition to historic bluff retreat data, future increase in storm or El Niño events, and any known site-specific conditions. The report should be completed by a licensed Geotechnical Engineer or an Engineering Geologist.

✓ **Include sea-level rise in tsunami hazard assessments:** Sea-level rise should be included in tsunami hazard assessments, including in tsunami wave runup calculations.

✓ **Site and design development to minimize risks from sea-level rise:** Update siting and design requirements to ensure development is safe from hazards associated with sea-level rise for the full projected life of the structure, without the use of shoreline protective devices. If it is not feasible to site development away from hazards, elevate above the base Flood Elevation (as defined by FEMA) adjusted for projected sea-level rise, and setback as far landward as possible.

- ✓ **Increase setback requirements:** Require new structures to be set back a sufficient distance landward to minimize risks, to the maximum extent feasible, over the life of the structure. For blufftop development, ensure development is set back from the bluff edge far enough that it will not be endangered by erosion, including sea-level rise over the life of the structure, without the use of any shoreline protective device, to the maximum extent feasible. The permit for new development should require it to be removed or relocated if it becomes threatened in the future.

- ✓ **Protect function of critical facilities:** Ensure critical facilities are able to function given sea-level rise. Use the upper range of sea-level rise as a minimum for siting and design of critical facilities. Consider developing a plan for relocation or retrofit of existing facilities located in hazardous areas.

- ✓ **Site and design wastewater disposal systems to avoid risks from sea-level rise:** Ensure wastewater disposal systems are not adversely affected by the effects of sea-level rise over the full life of the structure.

- ✓ **Require "soft" or "living" shorelines:** On appropriate shorelines, require new development to use "soft solutions" or "living shorelines" as an alternative to the placement of shoreline protection to enhance natural resource areas, dune restoration, sand nourishment, etc.

- ✓ **Consider a shorter development life for constrained lots**: When a lot is not large enough to provide a safe building area for the proposed life of the development without reliance upon protection or impacts to coastal resources, a shorter proposed life could allow development to occur for the short time period that the site can safely support such a use.

- ✓ **Ensure that current and future risks are assumed by the property owner**: New development should be undertaken in such a way that the consequences from development in high-hazard areas will not be passed on to the public or coastal resources.

- ✓ **Prohibit use of bluff retention or shoreline protection for new development, with the exception of coastal-dependent uses**: LCPs should have policies that require new development to be safe from bluff retreat, waves, or flood hazards without the use of any shoreline protective device. This policy preserves the ability of the shoreline to retreat naturally with changing conditions, which is especially important given projected changes from sea-level rise. LCPs should also require new development in potentially hazardous locations to include a waiver of rights to future shoreline protection. Shoreline protection is allowable for coastal-dependent uses under Coastal Act Section 30235.

- ✓ **Add conditions to shoreline protective devices that limit authorization of the device to the life of the existing development being protected:** The LCP can establish policies stating that permits for shoreline protective devices should be limited to the life of the existing development the protection device is designed to protect. At the end of that time period, the continued need for the structure should be re-evaluated and, if it is retained, appropriate mitigation for future effects should be required.

- ✓ **Require property owners to waive the right to shoreline protection in the future:** The LCP should require new development in potentially hazardous locations to include a waiver of the property owners' right to shoreline protection in the future.

- ✓ **Require mitigation for impacts of shoreline structures:** For unavoidable public resource impacts from shoreline structures permitted under the Coastal Act, require mitigation of resource impacts over the life of the structure as a condition of approval for the development permit. For example, for the loss of sandy beach due to shoreline protection devices, require landowners to pay a sand mitigation fee or complete other commensurate mitigation actions.

- ✓ **Develop an incentive program to relocate existing development at risk:** Provide incentives to relocate development out of hazardous areas and to acquire oceanfront properties damaged by storms, where relocation is not feasible. Consider creating a relocation fund through increased development fees, in lieu fees, or other funding mechanisms.

- ✓ **Establish a transfer of development credits program:** Consider creating a transfer of development credits program (TDC) or lot retirement program where new development located in hazardous areas must pay a fee or purchase development rights of properties identified by the land use plan to be in high-hazard sea-level rise zones or key conservation areas for wetland migration.

- ✓ **Develop or update shoreline management plans to address long-term shoreline change due to sea-level rise:** Create policies that require areas subject to wave hazards and erosion to develop a management plan, including strategies to manage changes in wave, flooding, and erosion hazards due to sea-level rise.

- ✓ **Establish a beach nourishment program and protocols:** New policies may be needed to address increased demand or need for beach nourishment with sea-level rise. Policies could establish a beach nourishment program and protocols for conducting beach nourishment, including measures to minimize adverse biological resource impacts from deposition of material, including measures such as timing or seasonal restrictions and identification of environmentally preferred locations for deposits.

- ✓ **Establish a sea-level rise planning and research program:** Add policies that establish actions to conduct long-term sea-level rise monitoring and research on areas of key uncertainties.

4.3 Public Access and Recreation

Suggested Changes to the LCP: Certified LCPs should already have policies and standards to assure that existing public access is protected and that maximum public access to and along the shoreline is both planned for and provided with new development when warranted. The LCP should also contain policies to maximize access to recreation and visitor serving facilities as a priority use under the Coastal Act. These policies may need to be updated to minimize impacts to public access, recreation sites or visitor-serving facilities due to sea level-rise.

What should the updated component include?

- ✓ **Update inventory and maps:** The LCP should include an updated inventory and maps of existing public access areas, recreation sites, and visitor-serving facilities at risk from sea-level rise, including:
  - o Vertical accessways
  - o Beaches
  - o Sections of the California Coastal Trail
  - o Any other recreation sites or related structures, including parking lots or boat ramps
  - o Areas suitable for new public accessways, parks and open space.

- ✓ **Update land use designations and zoning ordinances:** Update land use designations and zoning ordinances as applicable to provide for additional access, parklands, trail locations, recreation facilities, visitor-serving accommodations, etc. Establish land use standards to ensure an appropriate mix of visitor-serving accommodations over time.

- ✓ **Site and design access sites and facilities to minimize impacts:** Add policies that require public access sites, segments of the CCT, recreation and visitor-serving facilities to be sited and designed to avoid impacts from sea-level rise, while maximizing public access and recreation opportunities. Where facilities can be safely sited for the near term but

Potential impacts to Public Access and Recreation:

- Vertical accessways could become inaccessible.
- Loss of sandy beach area, including loss of lateral access
- Sections of the Coastal Trail could become eroded and inaccessible.
- Boat launch areas could become flooded and inaccessible.
- Loss of parks or recreation areas.
- Loss of visitor-serving facilities if threatened by sea-level rise.
- Loss of recreation opportunities, including change in surfing conditions, etc.
- Damage to structures that support recreation – picnic tables, restrooms, parking lots, etc.
- Increased demand for shoreline armoring projects to protect existing development with negative impacts on coastal access and recreation.

Actions to minimize impacts:

- Retrofit or relocate vertical accessways.
- Relocate or retrofit sections of the Coastal Trail through boardwalks, bridges, or other design features.
- Establish new accessways.
- Develop a sediment management and sand replenishment strategy.
- Plan for removal of structures that limit inland migration of beaches.
- Plan for future coastal recreational space and parkland by protecting existing open space adjacent to the coast.
- Retrofit or relocate recreation and visitor-serving facilities.
- Establish new recreation and visitor-serving facilities.
- Establish incentives for creation of new recreation opportunities, facilities and businesses.

future impacts are likely, require an adaptive management plan detailing steps for maintenance, retrofitting, and relocation.

- ✓ **Plan ahead to replace loss of visitor-serving accommodations:** Develop a plan to replace any visitor-serving accommodations that are lost due to impacts from sea-level rise, ensuring continued provision of affordable options, and an appropriate mix of accommodations over time.

- ✓ **Add requirements for retrofit/relocation of public access sites at risk:** The LCP can add policies that require all new public access and recreation areas, sections of the CCT, visitor-serving accommodations, or related recreation facilities to be retrofitted or relocated if they become threatened from erosion, flooding, or inundation. For facilities and public access sites located on private property, the requirements can be implemented through conditions of approval for new development that specify how maintenance, retrofit, or relocation will take place.

- ✓ **Require mitigation of any unavoidable impacts:** For unavoidable impacts to public access or recreation from shoreline armoring or other development, require mitigation of impacts through the addition of new public access, recreation opportunities, visitor-serving accommodations or Coastal Trail segments.

- ✓ **Incorporate sea-level rise into a comprehensive beach management strategy:** Update or develop a new comprehensive beach management strategy to address loss of beach areas, including loss of lateral access, or changes in beach management due to sea-level rise. Establish a program to minimize loss of beach area through, as may be appropriate, a beach nourishment program, restoring sand and sediment supply to littoral cell, removal or adjustments to shoreline protection structures, or other actions.

- ✓ **Support research on unknown impacts to recreation and public access:** Changes in sea level will affect wave conditions and sediment transport, but additional research is needed to understand how these changes will affect specific conditions for surfing and other recreation activities. To the extent possible, add policies to promote research on sea-level rise impacts to surfing or other recreation activities in the LCP jurisdiction.

- ✓ **Add policies to address impacts to transportation routes**: If transportation facilities are at risk from sea-level rise, establish new alternative transportation routes, or a plan to ensure continued alternative transportation and parking is available.

4.4 Coastal Habitats (ESHA, Wetlands, etc.)

Suggested Changes to the LCP:
LCPs should already have policies to protect ESHA, wetlands, riparian areas, and other natural resources in the coastal zone. Any existing policies should be evaluated to determine the extent to which the policies already address changes from sea-level rise. Additional policies may be needed to limit development in areas upland of wetlands, wildlife corridors, and important habitat linkages; to increase the size of buffer zones between development and natural resource areas; and to establish adaptive management plans for natural resource areas that account for sea-level rise.

What should the updated component include?

✓ **Update inventory and maps:** The updated LCP should include maps of existing wildlife corridors, habitat types and linkages, and natural resource areas; as well as maps of potential ecosystem change over time with sea-level rise. These maps can be generated through modeling with programs such as SLAMM (See Appendix D for a description). The LCP should also include an inventory of areas where habitats can migrate inland and where barriers exist that prevent migration. The LCP should also allow for the protection of wetlands and other coastal habitats that have not yet been mapped or identified.

✓ **Update land use designations and zoning to protect land adjacent to sensitive habitats:** Update land use designations and zoning to limit development in areas where coastal habitats could migrate inland as sea level rises.

- ✓ **Cluster development away from coastal habitats:** Existing LCPs will likely have policies that already require clustering of development. To address sea-level rise, these policies might need to be updated to include clustering development away from land where wetlands and other coastal habitats could migrate with sea-level rise.

- ✓ **Limit subdivisions:** Update subdivision requirements to limit any new land divisions, including lot line adjustments, in areas where natural resource areas could migrate inland or to require lots to be configured in a way that allows such migration.

Potential impacts coastal habitats:

- Conversion and loss of habitats as intertidal zones shifts inland.
- Loss of wetland habitat where inland/upslope migration of habitat cannot keep pace with sea-level rise due to natural or anthropogenic barriers.
- Loss of sandy beach habitat, haul-out sites, nesting habitat, nursery areas for fish, and migratory bird habitat.
- Rapid increase in the retreat rate of dunes.
- Potential loss of rare plants.
- Salinization and saltwater intrusion.

Actions to minimize impacts:

- Protect wildlife corridors, habitat linkages, and land upland of wetlands to allow habitat migration.
- Increase size of buffer zones.
- Restore natural sediment sources to wetlands.
- Update habitat management plans to address sea-level rise.
- Use an adaptive management approach in ecosystem restoration or design.
- Establish conservation easements to protect habitat.
- Cluster development away from habitat areas.
- Connect habitats to allow species movement.
- Protect refugia areas.

- ✓ **Consider sea-level rise buffer zones:** Update buffer zone policies to allow room for coastal habitats to migrate with changes in sea level. Buffer size will depend on site-specific factors including natural and artificial landform features. For instance, in flat areas, a larger buffer may be needed, but in steep areas, a smaller buffer would be acceptable.

- ✓ **Include sea-level rise in site-specific evaluations:** Update policies to require site-specific biological evaluations and field observations of coastal habitat to include an evaluation of vulnerability to sea-level rise. Such an evaluation should consider both topographic features as well as habitat and species sensitivities (for example, sensitivity to inundation and saltwater intrusion).

- ✓ **Update policies to provide for new or restored coastal habitat:** Update policies to require new coastal habitat to be provided or degraded areas to be restored to account for the expected loss of existing habitat that will occur with sea-level rise, using an adaptive management approach where applicable. Consider including a "no-net loss" of coastal habitat types as an LCP policy.

- ✓ **Update requirements for coastal habitat management plans:** Add policies stating that the effects of sea-level rise should be addressed in management plans for coastal habitats. Management plans should evaluate the full range of sea-level rise impacts to coastal habitats, and develop a strategy for managing coastal habitats given changing sea-level rise conditions. The plan should establish an adaptive management approach, with clearly defined triggers for adaptive actions. Existing management plans may need to be updated to add new monitoring and restoration requirements to address sea-level rise.

- ✓ **Updating monitoring requirements for coastal habitats:** As part of the LCP, consider establishing a monitoring protocol and requirements for evaluating sea-level rise impacts to coastal habitats over time.

- ✓ **Require open space protection as a component of new development located adjacent to coastal habitats:** In certain areas, the LCP can require as a permit condition that new development protect buffers around natural resource areas through a conservation easement, deed restrictions, or other comparable mechanism. Consider using rolling conservation easements that move inland over time to allow habitat to shift with sea-level rise.

- ✓ **Identify areas for public acquisition:** The LCP can establish a program to partner with state, federal, and non-profit organizations to acquire and protect natural resource areas for public use, including areas that could serve as refugia for species impacted by sea-level rise, or areas that could be appropriate sites for coastal habitat creation or restoration.

- ✓ **Pursue strategies to protect ecosystem function under a range of future sea-level rise or climate change scenarios:** The LCP can recommend coastal habitat management strategies that strive to protect ecosystem function in the future. Strategies include protecting a wide range of ecosystem types, protecting refugia, protecting wildlife and habitat corridors, and establishing methods to monitor ecosystem change over time.

- ✓ **Identify opportunities for Regional Sediment Management**: Sediment supplies will be important for the long-term sustainability of many beaches and wetland areas. Strategies to maintain or restore natural sediment supplies and to coordinate sediment removal efforts with opportunities for reuse, can provide multiple benefits to coastal ecosystems.

4.5 Agricultural Resources

Suggested Changes to the LCP:
The existing LCP should have policies to protect agriculture as a priority use in the Coastal Zone. Agriculture policies may need to be updated to address saltwater intrusion in coastal aquifers on agricultural lands and to identify additional areas for agriculture to replace any areas lost to sea-level rise.

What should the updated component include?

- ✓ **Update inventory and maps:** The updated LCP should include an updated inventory and map of all prime and non-prime agricultural areas, showing vulnerability of areas to sea-level rise.

- ✓ **Limit conversion of non-prime agricultural land:** Anticipate areas that could become more difficult to farm and identify strategies to avoid or mitigate the potential impacts. Develop policies to assure maximum protection of rural agricultural land, open space, and other coastal resource values.

- ✓ **Establish incentives for conservation easements:** Encourage conservation easements in areas vulnerable to sea-level rise. Easements could allow conversion of agricultural land to marsh where appropriate.

- ✓ **Add policies to address saltwater intrusion:** Add policies to manage water supply issues resulting from saltwater intrusion, such as limits on groundwater withdrawal or diversification of water supplies.

- ✓ **Include sea-level rise in water quality protection policies:** Where needed, add policies to reduce water pollution from runoff should agricultural lands become flooded or inundated due to sea-level rise.

Potential Impacts to Agriculture:

- Increase in flooding and inundation of low-lying agricultural land.
- Saltwater intrusion into water supplies.
- Decrease in the amount of freshwater available for agricultural uses.
- Crops may no longer be suitable for areas.
- Economic losses from damage to crops.
- Diversification of water supplies
- Loss of natural flood protection.

Actions to Minimize Impacts:

- Identify and rezone areas suitable for future agricultural production to replace areas lost to sea-level rise.
- Limit conversion of agricultural land to other uses.
- Encourage conservation easements for areas vulnerable to sea-level rise.
- Reduce pumping and avoid overdraft in coastal aquifers.
- Relocate wells and water intake facilities.
- Identify alternate water sources for agriculture.
- Maximize water conservation
- Minimize water quality impacts from flooding of agricultural lands
- Maintain dunes and other natural flood protection

✓ **Include policies to protect agricultural barriers:** If coastal dunes provide the main flood protection for agricultural lands, add policies to encourage long-term sustainability of the dune systems.

4.6 Water Quality

Suggested Changes to the LCP:
Certified LCPs should include policies to reduce nonpoint source pollution, including policies to minimize introduction of pollutants, minimize increases in peak runoff rate, restore impaired waters, incorporate effective site design and source control using Best Management Practices (BMPs), preserve functions of natural drainage systems, minimize impervious surfaces, and facilitate the infiltration of runoff. In addition to controlling polluted runoff, these policies will also help mitigate the impacts of sea-level rise. The updated LCP should evaluate whether new policies will be needed to minimize any additional impacts on water quality due to inundation of ocean outfalls, saltwater intrusion into water supplies, and potential increases in nonpoint source pollution.

The LCP should continue to promote principles of low impact development, protection and expansion of pervious surfaces, and implementation of other BMPs that reduce nonpoint pollution and increase infiltration of stormwater.

Potential impacts to water quality:

- Increase in nonpoint source pollution from flooding and inundation of impervious surfaces, industrial sites, or toxic soils.
- Ocean outfalls could become inundated with seawater and backflow, causing inland flooding of polluted water.
- Saltwater intrusion into water supplies.

Actions to minimize impacts:

- Retrofit or relocate outfalls deemed “at risk”.
- Reduce pumping and avoid overdraft in coastal aquifers.
- Relocate wells and water intake facilities.
- Identify and remediate toxic soils and contaminated sites at risk from sea-level rise.
- Conduct research and monitoring to more precisely understand local issues.

What should the updated water quality section include?

✓ **Clearly define areas at risk:** The LCP should include an updated inventory of potential pollutant sources due to sea-level rise, including toxic waste sites, ocean outfalls and wastewater treatment facilities at risk of inundation, as well as aquifers and wells at risk of saltwater intrusion.

✓ **Add policies to address water quality risks from ocean outfalls:** Consider establishing a program to retrofit or relocate ocean outfalls deemed at risk.

✓ **Add policies to address saltwater intrusion in aquifers:** Consider adding policies that establish a long-term strategy for addressing saltwater intrusion in aquifers, including limiting the use of sensitive aquifers as applicable. For some areas of the state, additional information is needed on the site-specific impacts of sea-level rise on aquifers. For these areas, the LCP could promote the establishment of a research program to increase understanding of the vulnerability of coastal aquifers.

- ✓ **Update water quality Best Management Practices:** Evaluate and update BMPs to account for changes in water quality issues due to sea-level rise, as applicable.

- ✓ **Update siting and design policies:** Add policies to ensure that new ocean outfalls, wastewater treatment facilities, and other facilities that could negatively impact water quality if flooded or inundated are sited and designed to minimize impacts from sea-level rise.

4.7 Archeological and Paleontological Resources

Suggested Changes to the LCP:
The existing LCP should have policies that specify requirements for maintaining information on the location of the known and suspected locations of archaeological and paleontological resources in the coastal zone, as well as how to proceed if resources are uncovered during the development process.

Potential Impacts to Archeological and Paleontological Resources:

- Damage to resources from erosion or flooding.

Actions to Minimize Impacts:

- Consult with relevant tribes for guidance.

What should the updated component include?

- ✓ **Update inventory and maps:** Update file of known and suspected resources, showing any potential risks from sea-level rise. File should be kept confidential in order to prevent vandalism to sites. Consult with tribal groups.

- ✓ **Add policies to protect archeological and paleontological resources from sea-level rise:** Add policies to require site-specific evaluation of potential sea-level rise impacts to archeological and paleontological resources on a development site. If resources are at risk, the appropriate entity or Native American tribes should be contacted to develop a management plan for artifacts. The LCP can also add requirements that a monitoring program and plan be established as a condition of approval for development located on a site with artifacts vulnerable to sea-level rise.

4.8 Scenic Resources

Suggested Changes to the LCP:
Certified LCPs should have policies that protect scenic resources. Many have addressed scenic resources through the designation of special communities, such as a historic community. Some adaptation measures may adversely affect public views of coastal areas or degrade the visual character of special communities. LCPs should include policies to protect scenic resources.

What should the updated component include?

- ✓ **Update inventory and maps:** Update inventory and maps of scenic areas and identify any that are in areas that could be affected by sea-level rise or adaptation measures.
- ✓ **Update land use designations and zoning ordinances:** Consider updating zoning requirements to avoid or minimize adaptation measures (such as elevation of structures to address flooding) that might result in adverse impacts to scenic resources or community character.
- ✓ **Establish design standards to protect visual resources:** Update design standards to ensure that adaptation measures protect visual resources while minimizing hazards

Potential Impacts to Scenic Resources:

- Elevation of structures to minimize flood risk could have scenic resource impacts.
- Increased demand for shoreline armoring to protect existing structures, with negative impacts on visual resources.

Actions to Minimize Impacts:

- Develop or redevelop property to be safe from hazards without impairing scenic resources.
- Establish new scenic communities in areas where significant visual resources could be diminished from adaptation responses (i.e. due to seawalls or spider homes).
- Add design standards to protect visual resources while minimizing hazards.

4.9 Energy, Industrial, and other Coastal Development

Suggested Changes to the LCP:
What should the updated component include?

- ✓ **Update inventory and map:** Update inventory and maps of existing energy facilities and coastal dependent industries within the coastal zone, showing areas likely to be affected by sea-level rise.
- ✓ **Update land use designations:** Update land uses as needed based on sea-level rise impacts and compatible uses.
- ✓ **Include sea-level rise in all actions related to energy, industrial:** Include policies to require industrial and energy facility expansion plans and proposals to include sea-level rise.

Potential impacts to Energy, Industrial and other Coastal Development

- Property damage from flooding and erosion due to sea-level rise
- Impaired function of facilities
- Potential need for decrease in dredging in marinas.
- Potential difference in heights between ships and cargo handling facilities and drydock/ship repair facilities.

Actions to minimize impacts:

- Design facilities to incorporate sea-level rise.
- Update land uses where applicable.
- Relocate or redesign existing facilities at risk.

> ***Expected outcomes from step #4**: Identified sections of the LCP that need to be updated, a list of adaptation measures applicable to the LCP, and new policies and ordinances to implement the adaptation measures.*

Step 5 – Update or Develop LCP and Certify with the Coastal Commission.

The next step is to incorporate the LCP policies that address sea-level rise into a new LCP or an updated LCP amendment. For jurisdictions with a certified LCP, adaptation measures will be implemented through development of amendments to the certified LCPs. For jurisdictions that currently do not have a certified LCP, the sea-level rise policies will be part of the development of a new LCP. In areas without a certified LCP, the Coastal Commission retains permitting authority, and the standard of review for any development is the California Coastal Act. Thus, it is important for local governments without certified LCPs to complete the planning and certification process.

As noted in step 4, sea-level rise has the potential to affect many types of Coastal Act resources in an LCP planning area/segment, and it is likely that policies in each Chapter of the LCP will need to be revised or developed to address impacts from sea-level rise. Two major types of updates to the LCP will likely be needed to address sea-level rise:

1. New or revised policies/ordinances that apply to all development in the planning area. For example, policies such as "All new development should be sited and design to minimize risks from sea-level rise over the life of the structure."
2. Updated land use and zoning designations, as well as programs to facilitate adaptive community responses, to reduce risks to specific coastal resources. For example, the LCP could modify the zoning of undeveloped land located upland of wetlands from residential to open space in order to provide the opportunity for wetlands to migrate inland, and protect wetlands for the future.

Local government staff should work closely with Coastal Commission staff and relevant stakeholders to develop the new LCP or LCP amendments. Once the updates and plans are complete, local governments will submit to the Commission for certification. Certification of plans can be an iterative process. Many times the Commission will approve a plan with modifications, at which point the local government is required to complete the modifications and resubmit to the Commission for final certification within a certain period of time.

Step 6 - Monitor and revise as needed.

An important component of successful adaptation is to regularly monitor progress and results, and update any policies and approaches as needed. Sea-level rise projections should be evaluated at least every five years.

- **Identify key resources to monitor:** Certain species can be indicators of whether sea-level rise is affecting an ecosystem. For instance, the presence of certain species can indicate the salinity of soils.

- **Periodically Update LCPs:** Local governments should try to review their vulnerability and risk assessments on a regular basis as significant new scientific information becomes available and propose amendments as appropriate. Given the evolving nature of sea-level rise science, policies may need to be updated as major scientific advancements are made, changing what is considered the best available science. Regular evaluation of policies is important to make sure policies and adaptation strategies are effective in reducing impacts from sea-level rise.

This six-step process is illustrated below in the flowchart (Figure 5). Notice that the process is circular. Because sea-level rise science will be refined and updated in the future, planners should periodically repeat this six-step process to update and improve their LCPs.

For additional resources and examples of ways to incorporate sea-level rise into the LCP, see Appendix C.

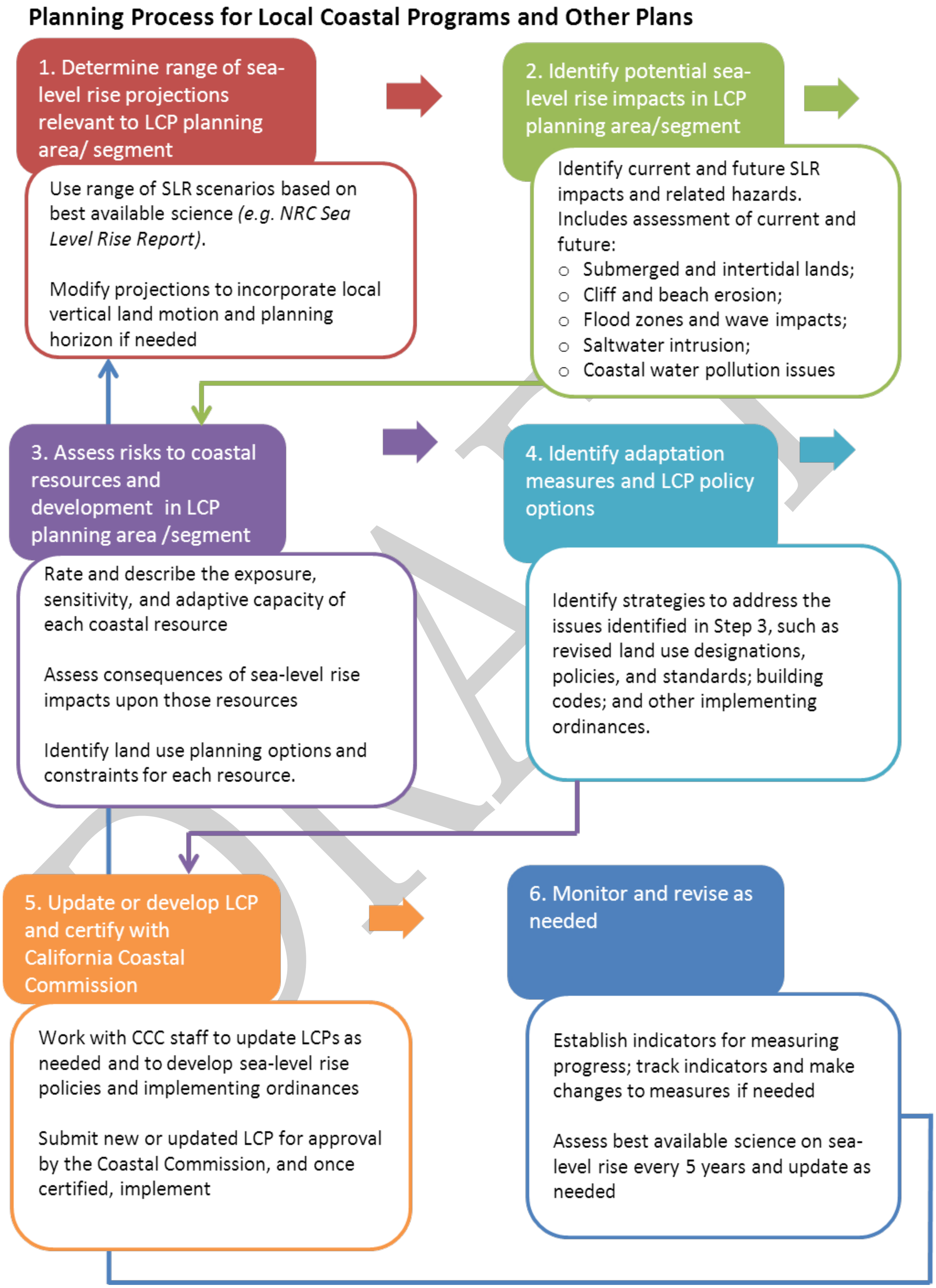

Figure 5. Flowchart for Addressing Sea-Level Rise in Local Coastal Programs and other Plans

V. ADDRESSING SEA-LEVEL RISE IN COASTAL DEVELOPMENT PERMITS

New development in the coastal zone generally requires a coastal development permit (CDP).[20] In areas without a certified LCP, the Commission is generally responsible for reviewing the consistency of CDP applications with the policies of Chapter 3 of the Coastal Act (Public Resources Code sections 30200-30265.5). In areas with a certified LCP, the local government is responsible for reviewing the compliance of CDP applications with the requirements of the certified LCP and, where applicable, the public access and recreation policies of the Coastal Act. Certain local government actions on CDP applications are appealable to the Commission. On appeal, the Commission also applies the policies of the certified LCP and applicable public access and recreation policies of the Coastal Act. The Commission and local governments may require changes to the project or other mitigation measures in order to assure compliance with Coastal Act policies or LCP requirements and both minimize risks to the development from coastal hazards and avoid impacts to coastal resources.

Many of the projects reviewed through the CDP application process already examine sea-level rise as part of the hazards analysis. Such examination will need to continue, and these guidelines offer direction and support for thorough examination of sea-level rise and its associated impacts based on current climate science, coastal responses to changing sea level and consequences of future changes.

All locations currently subject to inundation, flooding, wave impacts, erosion or saltwater intrusion will be exposed to increased risks from these coastal hazards with rising sea level. Locations close to or hydraulically connected to these at-risk locations, will themselves be at-risk as sea level rises and increases the inland extent of these hazards. To comply with Coastal Act Section 30253 or the equivalent LCP section, projects will need to be planned, located, designed and engineered for the changing water levels and associated impacts that might occur over the life of the development. In addition, project planning should anticipate the migration and natural adaptation of coastal resources (beaches, access, wetlands, etc.) due to these future sea-level rise conditions in order to avoid future impacts to those resources from the new development.

[20] Coastal Act Section 30106 defines "Development" to be, "on land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice Act of 1973 (commencing with Section 4511)."

Steps for Addressing Sea-Level Rise in Coastal Development Permits

The following steps provide general guidance for addressing sea-level rise in the project design and permitting process.

Step 1: Establish the projected sea-level rise range for the proposed project
Step 2: Determine how impacts from sea-level rise may constrain the project site
Step 3: Determine how the project may impact coastal resources, considering the influence of future sea-level rise upon the landscape
Step 4: Identify project design alternatives to both avoid impacts to coastal resources and minimize risks to the project
Step 5: Finalize project design and submit CDP application

The goal of these steps is to ensure careful attention to minimizing development risk and to avoid impacts to coastal resources in light of current conditions and the changes that may arise over the life of the project. Many project sites and proposed projects may raise issues not specifically contemplated by the following guidance steps or the permit filing checklist at the end of this section. Notwithstanding, it remains the responsibility of the project applicant to adequately address these situations so that consistency with the Coastal Act and/or LCP may be fully evaluated. Throughout the CDP analysis, applicants are advised to contact planning staff (either at the Commission or the local government, whichever is appropriate) to discuss the proposed project, project site, and possible resource or hazard concerns. The extent and frequency of staff coordination may vary with the scale of the proposed project and the constraints of the proposed project site. Larger projects and more constrained sites will likely necessitate greater coordination with local government and Commission staff.

Step 1 - Establish the projected sea-level rise range for the proposed project

A projected sea-level rise range should be obtained from the best available science. Those projections should be adjusted for local conditions and cover the expected design or economic life of the proposed project, as the ultimate objective will be to assure that the project is safe from coastal hazards, without the need for shoreline protection or other detrimental hazard mitigation measures, as long as it exists.

- **Define Expected Project Life or Design Life**: The expected or proposed project life will help determine the amount of sea-level rise to which the project site could be exposed while the development is in place. Some LCPs include a specified design life for new development. If no time frame is provided, a minimum of 75 to 100 years should be considered as the design life for primary residential or commercial structures. An indefinite time period might be appropriate for resource protection or enhancement projects such as a trail or coastal habitat conservation or restoration project. A long, but defined time period may be appropriate for critical infrastructure. A shorter time period might be appropriate for ancillary development, amenity structures, or moveable or expendable construction. The proposed project life may need be to be shortened if subsequent steps identify that the project site is constrained by hazards (such as flooding, erosion or steep slopes) or contains coastal resources (such as wetlands, ESHA or cultural resources) such that development cannot be sited and designed to be safe for a 50- or 75-year proposed life, without reliance upon protection efforts or impacts to the coastal resources.

- **Determine Sea-Level Rise Range:** The project analysis should use a range of sea-level rise projections based on the best available science. At present, the 2012 NRC report is considered to be the best available science. Appendix B provides information on how to determine sea-level rise amounts for years that are not included in the NRC report and, if needed, how to modify the NRC sea-level rise projections to account for local vertical land motion. At a minimum, low and high sea-level rise projections for the proposed life of the project should be used for project analysis and evaluation.

  For project locations in the vicinity of Humboldt Bay and the Eel River estuary, the regional NRC sea-level rise projections will need to be modified to adjust for localized vertical land motion, and this is discussed further in Appendix B. Adjustments for vertical land motion are not recommended for other locations.[21] However, if sea-level rise projections are modified for areas other than the Humboldt Bay region, at least one scenario for the analysis of impacts should use the high value from the unmodified NRC projections.

Expected outcomes from step #1*: This step should provide a proposed or expected project life and corresponding range of sea-level projections that will be used in the following analytic steps. If subsequent steps establish that the proposed site is too constrained for the proposed development to remain safe for the full project life without reliance upon additional protection measures and resources impacts, the expected life of the development may need to be modified to allow a shorter period for use of the proposed site.*

CDP Application Information from Step #1: *This step should provide information on the proposed project life and the range of sea-level rise projections to be used in project analysis.*

Step 2 - Determine how impacts from sea-level rise may constrain the project site

The Coastal Act requires that development minimize risks from coastal hazards. Sea-level rise can both present new hazards and exacerbate hazards that are typically analyzed in CDP

[21] A three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City. The OPC-SAT subcommittee stated, “We do not believe that there is enough certainty in the sea-level rise projections nor is there a strong scientific rationale for specifying specific sea-level rise values at individual locations along California’s coastline.” (OPC, 2013, pg. 10)

applications. In this step, determine the extent of sea-level rise impacts now and into the future, and determine how to minimize those hazards when siting the project.

Impacts associated with sea-level rise generally include erosion, inundation, flooding, wave impacts, and saltwater intrusion. An assessment of these impacts often is required as part of a routine hazards assessment or the safety element of the LCP. Therefore, information in the local LCP can provide an initial determination of concern for the project in question, if available. However, proposed development will often need a second-level, site-specific analysis of hazards to augment the more general LCP information.

2.1 Analyze relevant sea-level rise impacts.

A CDP application for new development in a hazardous area should include reports analyzing of the anticipated impacts to a project site associated with rising sea level. Generally, the analyses pertinent to sea-level rise include geotechnical stability, erosion, and flooding/inundation, and these analyses are described in detail below. Depending on the site, however, different analyses may be required. Applicants should work with planning staff (Coastal Commission or local government staff) to perform a pre-application submittal consultation to determine what analyses are required for their particular project. After the submission of the CDP, any additional analyses that are required will be listed in an application filing status review letter.

The professionals who are responsible for these studies are familiar with the methodologies for examining their respective impacts. However, the methodologies sometimes do not always adequately examine potential impacts under rising sea level conditions, as established by best available science. Appendix B goes through the various steps for incorporating the best available science on sea-level rise into the more routine analyses, which are summarized below:

- **Geologic Stability:** The CDP should analyze site-specific stability and structural integrity without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caisson foundations) that would substantially alter natural landforms along bluffs and cliffs. In most situations, this stability analysis will be combined with the erosion analysis (below) to fully establish the safe developable area.

- **Erosion:** The CDP application should include an erosion analysis and map illustrating the extent of erosion that potentially could occur from current processes, as well as future erosion hazards associated with low and high sea-level rise scenarios over the life of the project. If possible, these erosion conditions should be shown on a site map, and the erosion zone used to help establish locations on the parcel or parcels that can be developed without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caissons) that would substantially alter natural landforms along bluffs and cliffs. In most situations, this erosion analysis will be combined with the geologic stability (above) to fully establish the safe developable area. And, if the analyses show that the proposed development cannot be safe over the proposed project life, without reliance upon protection or impacts to resources, the proposed project life may need to be shortened.

- **Flooding and Inundation:** The CDP application should include analysis of the extent of flooding or inundation that potentially could occur over the anticipated life of the project from a minimum of low and high sea-level rise scenarios, and under a range of conditions that could include high tide, storm surge, water elevation due to El Niños, Pacific Decadal Oscillations, a 100-year storm event, and the combination of long-term erosion and seasonal beach erosion. If possible, this information and resulting flood zones should be shown on a site map.
    - **Flood Elevation Certificate**: If a site is within a FEMA-mapped 100-year flood zone, building regulations, in implementing the federal flood protection program, require new residences to have a finished floor elevation above Base Flood Elevation (BFE) (generally one foot). The CDP application should include a flood elevation certificate prepared by a registered land surveyor, engineer, or architect, demonstrating that the finished floor foundation of the new structure will comply with the minimum FEMA guidelines and building standards. At this time, the Flood Certificate does not address sea-level rise related flooding. Thus, in general, a certificate is not adequate to address Coastal Act and LCP standards for demonstrating that future flood risk has been minimized. In addition, designing to meet FEMA requirements may be in conflict other resource constraints, such as protection of visual resources, community character, and public access and recreation.
- **Other Impacts**: Any additional sea-level rise related impacts that could be expected to occur over the life of the project, such as saltwater intrusion should be evaluated. This may be especially significant for areas with a high groundwater table such as wetlands or coastal resources that might rely upon groundwater, such as agricultural uses.

2.2 Evaluate the sea-level rise impacts resulting from multiple sea-level rise scenarios.

Because there is scientific uncertainty associated with sea-level rise projections, sea level projections for a certain time period are usually given as a range. (For example, the NRC predicts 10 – 143 centimeters of sea-level rise by 2100 for land north of Cape Mendocino.) Therefore, applications should analyze the hazards that may result from both the low and high bounds of these ranges, along with medium values if necessary. This technique is called scenario-based analysis: it examines hazards such as inundation, flooding, wave impacts and erosion for various levels of sea level that can be expected to occur over the life of the development. The analysis of various sea-level rise scenarios will allow the project planners to understand project vulnerabilities, including tipping points where the response of the project to sea-level rise will change significantly (for example, transitioning from periodic flooding to inundation, or rapid acceleration of erosion).

This guidance recommends that at least two sea-level rise scenarios be analyzed – a low and high amount of sea-level rise. For example, for a proposed development location that might only be at risk from flooding at the end of its expected economic life and with a high projection of sea-level rise it might be appropriate to address this future flood risk through future adaptation whereas flood risks for a site that will be at risk from flooding with a very small projection of sea-level rise might need to address these future risks through more immediate steps. Therefore, it is important that the analyses for a proposed project examine the consequences associated with a range of sea-level rise projections appropriate to the project's expected life.

If there are large changes in the hazard zones between these two sea-level rise amounts, additional analyses may help determine the tipping points. Such tipping points might be indications of constraints to the site, such that its use as a development site may be severely constrained sometime in the future.

Finally, scenario-based analyses can help determine the long-term compatibility of the proposed site and the proposed development. The impacts analyses may identify that the proposed site cannot safely be used for the proposed project life. If this is the case, additional analyses for a shorter proposed project life may be appropriate.

Expected outcomes from step #2*: This step should provide detailed information about the sea-level rise related impacts that can occur on the site and changes that will occur over time. High risk and low risk areas of the site should be identified. The scenario-based analyses should also provide information on the amount of sea-level rise that could occur over the proposed development life, without relying upon existing or new protective devices. This step should also determine whether the project site will be constrained by hazards such that the proposed project life should be modified.*

CDP Application Information from Step #2: *This step should provide information and maps of the site-specific hazards and areas that can safely support development. Site-specific hazards include areas of geologic instability, erosion, flooding, inundation, and potentially saltwater intrusion or groundwater elevation.*

Step 3 - Determine how the project may impact coastal resources, considering the influence of sea-level rise upon the landscape over time

The Coastal Act requires that development avoid impacts to coastal resources. Sea-level rise will cause likely coastal resources to change over time. Therefore, in this step, analyze how sea-level rise will affect coastal resources now and in the future so that alternatives can be developed in Step 4 to minimize the project's impacts to coastal resources throughout its lifetime.

All coastal resources – public access and recreation, water quality, natural resources (such as ESHA and wetlands, etc.), agricultural resources, natural landforms, scenic resources, and archeological and paleontological resources – will need to be considered in this step. As in Step 3, this analysis should be repeated using both the low and high bounds of the range of sea-level rise projections that are appropriate for the expected life of the project should be used in the analysis. Also, if the proposed project may be changed or modified during the initial project design stage, or due to future adaptation, the resource impacts of these changes must also be analyzed.

3.1 Analyze coastal resource impacts and hazard risks

Analysis of resource impacts will require information about the type and location of the resources on or in proximity to the proposed project site. The following discussion of each resource will help identify the key impacts to each that might result from either sea-level rise or the proposed development. If coastal resources will be affected by sea-level rise, such as changes to the area and extent of a wetland or riparian buffer, these changes must be considered in the analysis. Much of the following discussion recommends analysis of impacts from current and future inundation, flooding, and erosion. Appendix B provides guidance on how to undertake this analysis and includes lists of suggested resources that can provide data, tools, or other resources to help with these analyses.

Information on the following resources is included. To skip to a section, click on the links below:

- New Development
- Public Access and Recreation
- Coastal Habitats
- Natural Land Forms
- Agricultural Resources
- Water Quality
- Archeological and Paleontological Resources
- Scenic Resources

New Development

New development must be sited and designed to minimize risks from hazards. Consider the following steps to identify potential risks from hazards:

- ✓ Identify all hazards that may impact the proposed project site or proposed development. Such hazards can include shoreline erosion, bluff erosion, flooding, inundation, elevated ground water, and saltwater intrusion. Once hazards are identified, if possible map these hazards in relation to the location of the proposed project.

- ✓ Determine whether any hazard zones will be altered or affected by sea-level rise over the proposed life of the project. Sea-level rise will alter the extent of flooding, inundation as well as the rates of shoreline and bluff erosion. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to hazard zones.

- ✓ If any natural landforms will be altered by sea-level rise, map or otherwise identify the likely changes to location of these coastal resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development without being located within a hazard zone. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

Public Access and Recreation
Public access and recreation resources include lateral and vertical public accessways, public access easements, beaches, recreation areas, public trust lands,[22] and trails, including the California Coastal Trail. These areas may become hazardous or unusable during the project life due to sea-level rise. Steps to identify potential risks to public access and recreation include:

- ✓ Identify all public access locations on or near the proposed project site and, if possible, map these resources in relation to the location of the proposed project.

- ✓ Determine whether any access locations will be altered or impacted by sea-level rise over the proposed life of the project. Such impacts could result from flooding, inundation, or shoreline erosion. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to public access and recreation.

- ✓ If any access locations will be altered by sea-level rise, map or otherwise identify the likely changes to location of these access resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these access locations. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

Coastal Habitats (ESHA, wetlands, etc.)
Coastal habitats, especially those that have a connection to water, such as beaches, intertidal areas, and wetlands, can be highly sensitive to changes in sea level. Steps to identify potential resource impacts associated with the project include:

- ✓ Identify all coastal habitats on or near the proposed project site and, if possible map these resources in relation to the location of the proposed project.

- ✓ Determine whether any coastal habitats will be altered or affected by sea-level rise over the proposed life of the project. Such impacts could result from flooding, inundation, shoreline erosion, or changes to surface or groundwater conditions (see discussion below on water quality). At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to coastal habitats.

[22] The State Lands Commission has oversight of all public trust lands and they should be contacted if there is any possibility that a public trust lands might be involved in the proposed project. As a general guide, public trust lands can include, but not be limited to tide and submerged lands.

- ✓ If any coastal habitats will be altered by sea-level rise, map or otherwise identify the likely changes to location of these coastal resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these coastal habitats. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

Natural Landforms
Natural landforms can include coastal caves, rock formations, bluffs and cliffs. Steps to identify natural landforms at risk include:

- ✓ Identify all natural landforms on or near the proposed project site and, if possible map these resources in relation to the location of the proposed project.

- ✓ Determine whether any natural landforms will be altered or impacted by sea-level rise over the proposed life of the project. Such impacts could result from flooding, inundation or shoreline erosion. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to natural landforms.

- ✓ If any natural landforms will be altered by sea-level rise, map or otherwise identify the likely changes to location of these coastal resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these natural landforms. Bluffs and cliffs can often require additional analysis for slope stability to determine the setback from the eroded bluff face that can safely support development. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

Agricultural Resources
Agricultural resources may be affected by sea-level rise through changes to surface drainage and the groundwater table. Other changes can result from flooding, inundation or saltwater intrusion. If agricultural lands are protected by levees or dikes, agricultural lands can be affected by changes to the stability or effectiveness of these structures. Steps to identify risks to agricultural resources include:

- ✓ Identify whether the proposed project site is used for or zoned for agricultural uses or is in the vicinity of or upstream of lands in agricultural use.

- ✓ Identify surface water drainage patterns across the site or from the site to the agricultural use site.

- ✓ If any drainage patterns are closely linked to and likely influenced by the elevation of sea level, examine changes in drainage patterns with rising sea level, both on the proposed site or the agricultural use site.

- ✓ Identify the elevation of the groundwater table. Since groundwater can fluctuate during periods of rain and drought, attempt to identify the groundwater zone.

- ✓ Estimate the likely future elevation of the groundwater zone, due to sea-level rise. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to groundwater.

- ✓ Evaluate whether changes in groundwater will alter the proposed site conditions.

Water Quality

Sea-level rise may cause drainages with a low elevation discharge to have water back-ups. It may also cause a rise in the groundwater table. Both these changes could alter on-site drainage and limit future drainage options. If the proposed site must support an on-site wastewater treatment system, or if drainage and on-site water retention will be a concern, consider the following, as appropriate:

- ✓ Identify surface water drainage patterns across the site.

- ✓ Examine changes in drainage patterns with rising sea level of any drainage patterns that are closely linked to and likely influenced by the elevation of sea level. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to drainage patterns.

- ✓ Identify the elevation of the groundwater table. Since groundwater can fluctuate during periods of rain and drought, attempt to identify the groundwater zone.

- ✓ Estimate the likely future elevation of the groundwater zone, due to sea-level rise. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed lift of the project to establish the zone of likely changes to groundwater.

- ✓ Evaluate whether changes in groundwater will alter the proposed site conditions.

Archeological and Paleontological Resources

The Coastal Act protects archeological and paleontological resources. However, there are other state and federal laws that govern the protection or disturbance of these sites and of the public disclosure of their locations. The appropriate state and federal agencies and tribal authorities should be involved with land use decisions involving archeological and paleontological resources. Steps to identify archeological and paleontological resources at risk include:

- ✓ Identify all archeological and paleontological resources on the proposed project site.

- ✓ Determine whether any archeological and paleontological resources will be impacted by sea-level rise, including impacts from flooding, inundation or shoreline erosion. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to archeological and paleontological resources.

- ✓ If any archeological and paleontological resources will be altered by sea-level rise, identify the likely changes to location of these coastal resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development and avoid or minimize impacts to archeological and paleontological resources. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

Scenic Resources
Visual and scenic resources include views to and along the ocean and scenic coastal areas. Development modifications to minimize risks to sea-level rise could have unintended negative consequences for scenic resources, including creating a structure that is out of character with the surrounding area and altering natural landforms. Steps to identify impacts to scenic resources include:

- ✓ Identify all scenic views to and through the proposed project site from public vantage points such as overlooks, access locations, beaches, trails, the Coastal Trail, public roads, parks, etc. and, if possible map these views and view lines in relation to the location of the proposed project.

- ✓ Determine whether any public vantage points will be impacted by sea-level rise, especially beaches, trails and the Coastal Trail. Such impacts could result from flooding, inundation or shoreline erosion. At a minimum, use a low and high projection of sea-level rise appropriate for the location and the proposed life of the project to establish the zone of likely changes to scenic resources.

- ✓ If any access locations, beaches, trails, the Coastal Trail or public trust lands will be altered by sea-level rise, map or otherwise identify the likely changes to location of these coastal resources over the life of the proposed project.

- ✓ Identify locations of the proposed project site that can support development and avoid or minimize impacts to scenic views from current and future vantage points. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, etc.) and with other coastal resource constraints.

3.2 Synthesize and assess development and resource constraints

After completing the detailed analysis of each coastal resource, the applicant should summarize the potential resource impacts. If feasible, applicants should produce a constraints map illustrating the location and the extent of resource impacts that could occur over the life of the development. Based on the analysis of resource impacts and potential hazard risks over the life of the development, the applicant should develop an overlay identifying the development and resource constraints.

3.3 Identify areas suitable for development

The final part of this step is to identify the locations of the project site that could support some level of development without impacts to coastal resources and without putting the development at risk.

Expected outcomes from step #3*: Upon completing this step, the applicant should have detailed information about the types of coastal resources on the project site and the level of risk that sea-level rise poses to each resource, including resource locations and the extent of resource impacts that could occur over the life of the proposed project. This step should also provide an overlay of all development and resource constraints, and clearly identify the locations on the proposed project site that could support some level of development without impacts to coastal resources and without putting the development at risk.*

Step 4 - Identify project design alternatives that avoid resource impacts and minimize risks to the project.

In this step, identify project alternatives and analyze their associated resource impacts and sea-level-related risks. Projects must be sited and designed to address all applicable Coastal Act and LCP requirements. This requires both that the proposed development minimize risks from coastal hazards and that the proposed development avoid impacts to coastal resources. The analysis of resource impacts and development risks (Step 3) will provide a good understanding of these two concerns – both the risks to the development and the extent and type of resource constraints that exist on the proposed project site.

Employ Hazard Avoidance whenever possible: The best way to minimize risks to life and property from sea-level rise related hazards is to avoid hazardous locations and to keep development out of harm's way. If feasible, development should not be proposed in locations subject to current or future risks from inundation, flooding or erosion. Depending upon the proposed development and proposed development site, it may be possible to site the entire proposed development in a low or non-hazardous location. The analysis of development risks and coastal resources (Step 3) will identify if there are locations on the proposed project site that can support development without need for future shoreline protection, bluff retention or impacts to coastal resources. If such locations are available, a development footprint can be established that avoids all hazard areas, without impacts to coastal resources.

In other situations, the proposed development may have to be modified or resized to fit within the low hazard portion of the site. In addition, land divisions, including lot line adjustments, in high hazard areas can change hazard exposure and should be undertaken only when they can be shown to not worsen or create new vulnerability. In particular, no new lots or reconfigured lots with new development potential should be created if they cannot be developed without additional shoreline hazard risks.

Employ Hazard Minimization when Avoidance is infeasible: If hazard avoidance is not possible, a second approach to minimize risks from natural hazards is to limit exposure to hazards, or the likelihood that a project could come into contact with the hazards. When hazard avoidance is infeasible, there are, in general, two basic approaches for minimizing sea-level rise related hazards while protecting coastal resources. These approaches depend upon whether or not the proposed project will likely need to stay in a fixed location or whether it can be easily relocated. If the project will be at a fixed location, the greatest opportunity for minimizing risks may come through siting and design for future sea level conditions, with adaptation options incorporated into the design in the event that sea level rises more than anticipated in the design. If the project itself can relocate and adapt to rising water levels, then the greatest opportunity for minimizing risks may come through future modifications to the structure or relocation, with this adaptive flexibility included in the initial siting and design. A wastewater treatment plant might be an example of the former and wetland restoration or a coastal trail might be an example of the latter. Of course, many projects might take a hybrid approach, assuming a fixed location, but incorporating incremental relocation, such as modular structures that are designed for some anticipated amount of sea-level rise, with options for removal as portions of the structure become threatened. Opportunities to ensure minimization of risks will be different for a very fixed type of development and one that can change or relocate. However, the key goal of either approach will be to site, design, modify or adapt proposed projects such that they remain safe from current and future sea-level rise associated hazards, and cause no current or future resource impacts.

Design Adaptation Strategies to minimize risks and avoid resource impacts. If it is not feasible to site or design a structure to completely avoid sea-level rise impacts over the anticipated life of the structure, the applicant should instead minimize impacts and develop a sea-level rise adaptation strategy, including steps to relocate or modify the development as needed to prevent risks to the development or to coastal resources. This process should be conducted as part of the alternatives analysis. See Appendix C for more information on adaptation measures. For a list of guidebooks, online clearinghouses, and other sea-level rise adaptation resources, see Appendix D.

Steps involved in designing an appropriate adaptation strategy may include:

- **Sea-Level Rise Design Amount:** If the likelihood of impacts is expected to increase with rising sea level, it may be necessary to design for some amount of sea-level rise and include design flexibility that will allow future project changes or modifications to prevent impacts if the amount of sea-level rise used in the design is not sufficient. The amount of sea-level rise used in this process may vary on a case-by-case basis.

- **Adaptation Options:** Evaluate each adaptation option for efficacy in protecting the development. Also, evaluate the consequences from each proposed adaptation measure to ensure it will not have adverse impacts on coastal and sensitive environmental resources, including visual impacts and public access.

For example, an option that is often considered for sea-level rise is to elevate the development or the structures that are providing flood protection. However, elevated structures will change the scenic quality and visual character of the area. Also, elevation of the main development may be of little long-term utility to the property owner if the supporting infrastructure, such as the driveways, roads, utilities or septic systems are not also elevated or otherwise protected. Elevation of existing levees or dikes can provide flood protection for an area of land and all the development therein. However, the foundation of the levee or dike must be augmented to raise the height of most levees, and the increased footprint of the foundation could have impacts on intertidal area, wetlands, or other natural resources. Thus, the long-term options for adaptation should be considered as part of any permit action, to ensure that current development decisions are not predetermining resource impacts in the future.

- **Design Constraints:** Determine whether there are any significant site or design constraints that might prevent future implementation of possible sea-level rise adaptation measures. Some project locations may be constrained due to lot size, sea level related hazards, steep slopes, fault lines, the presence of wetlands or other ESHA, or other constraints such that no safe development area exists on the parcel. Ideally, such parcels would be identified during the LCP vulnerability analysis, and the land use and zoning designations would appropriately reflect the constraints of the site. There may be few options for minimizing risks. Nevertheless, care should be taken to avoid, or minimize as appropriate, resource damages from current or future sea-level rise related hazard areas.

- **Monitoring:** Develop a monitoring program or links to other monitoring efforts to ensure that the proposed adaptation measures will be implemented in a timely manner. Carefully identify the triggers that would lead to project modifications or adaptation efforts. The expected project life may be a project element that could be modified to allow some development to occur now, but to allow for removal of the development as it becomes threatened by erosion or flooding, or as it causes impacts to coastal resources. This would be especially appropriate for project sites where the development might be safe for the low range of sea-level rise but not for the higher range of sea-level rise. A flexible project life could include various triggers or change points that would cause the project to be modified or removed before the end of the expected life of the development. This could allow some safe use of an otherwise constrained site and ensure long-term resource protection.

Expected outcomes from step #4*: This step may involve an iterative process of project modifications and reexamination of impacts, leading to one or more alternatives for the project site. The alternative that will minimize risks from coastal hazards and avoid or minimize impacts to coastal resources should be identified. Possible adaptation options could be identified and analyzed, if appropriate. If the site is very constrained, modifications to the expected project life might be suggested.*

Step 5 – Finalize project design and submit CDP application

After Step 4, the applicant should have developed one or more project alternatives. The alternatives should include adaptation strategies if hazards cannot be avoided entirely and are instead minimized. The next step involves the following:

1. **Work with the planning staff to complete the CDP application**. This step might involve an iterative process, wherein planning staff requests more information about the proposed project or project alternatives to help in review for compliance with the Coastal Act. This process may be repeated until the application provides the studies, analysis and project review necessary for planning review. The CDP application covers the general information needed for a complete CDP application. This guidance and the provided Filing Checklist for CDP Applications provides more specific guidance on information that will be needed for project sites that are likely to be subject to sea-level rise impacts over the life of the proposed development.

2. **Submit a complete CDP application.** Once a complete application is submitted, the planning staff will then review the permit, and if necessary request additional information or modifications to the project. Please consult the Coastal Commission website or contact your district office for instructions on how to complete a CDP application.

3. **Permit action.** The outcome of a permit submittal will be project approval, approval with conditions, or denial. Based on the regulatory decision, the project may be constructed, or additional modifications and condition requirements may have to be met.

4. **Monitor and revise.** CDP approvals will often include conditions that require monitoring. Applicants should monitor the physical impacts of sea-level rise on the project site and respond as necessary. Applicants may also monitor changes in sea-level rise science.

Expected outcomes from step #5*: This step, combined with supporting documentation from the previous steps, should provide a basis for evaluating the proposed project's hazard risks and impacts that can result from sea-level rise. Such an analysis will provide one of the bases for project evaluation and complements the other resource evaluations and analyses that are part of a complete CDP application.*

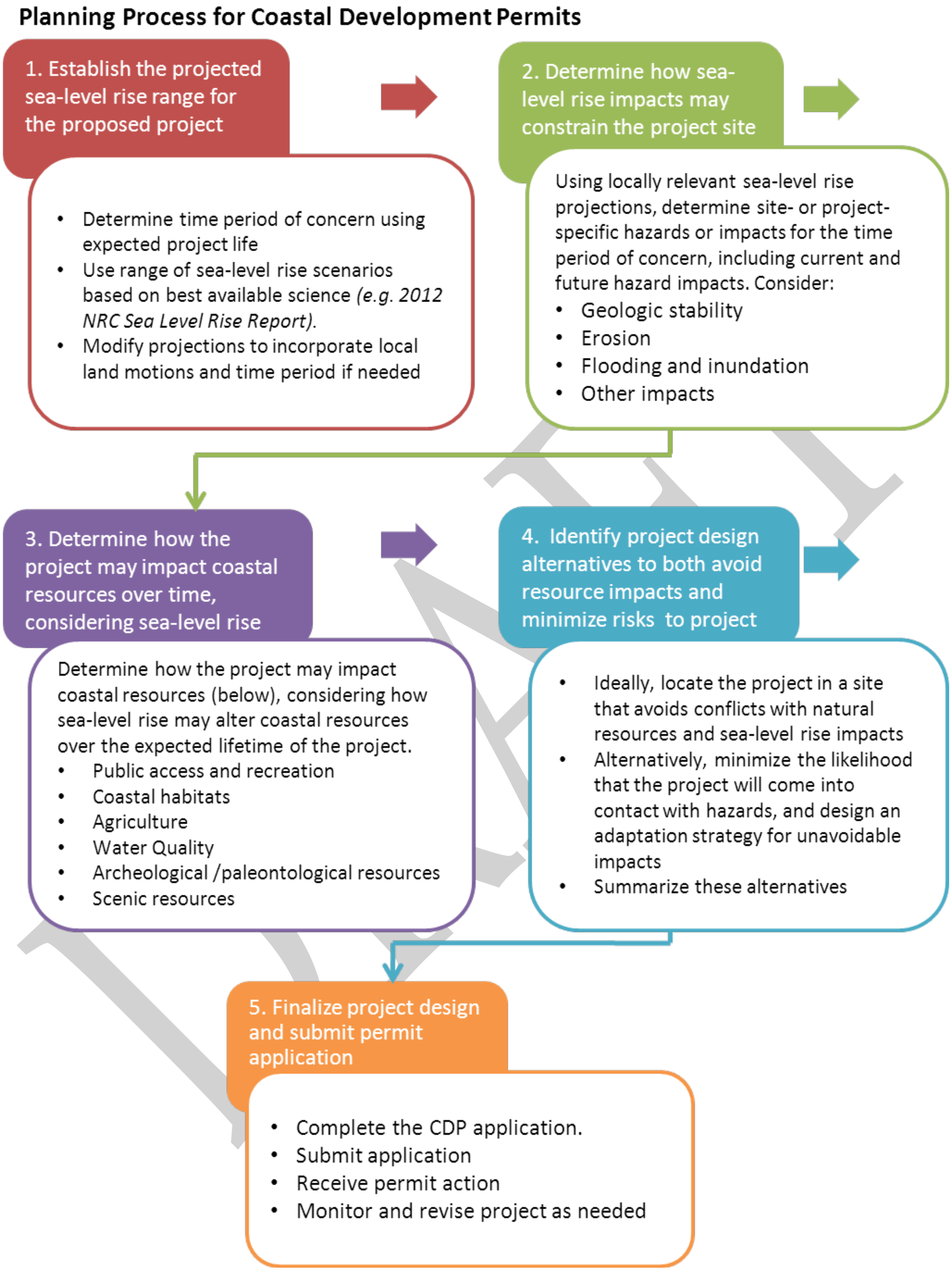

Figure 6. Flowchart for addressing sea-level rise in Coastal Development Permits

Filing Checklist for Sea-Level Rise Analysis

- Proposed/Expected Project Life, if appropriate.
- Sea-Level Rise Projections Used in Impacts Analyses
- Impacts Analyses (possibly from Vulnerability Assessment)
    - Structural and Geologic Stability
        - Perform Geotechnical Report and Erosion Analysis
        - Identify blufftop setback and safe building area
        - Show setback, safe building area and proposed project footprint (site maps)
    - Erosion Amount over Expected Project Life
        - Perform Coastal Processes Study and Erosion Analysis
        - Quantify total erosion amount for proposed project site
        - Show retreat along with proposed project footprint (site maps)
    - Flooding and Inundation Risks
        - Perform Coastal Processes Study and Wave run-up analysis
        - Quantify flood elevation and flooding extent
        - Show flood extent with proposed project footprint (site map)
        - Show flood elevation on site profile, with proposed project elevation
        - Provide Flood Certificate if in FEMA designated 100-year Flood Zone
    - Tipping points for Sea-Level Rise Impacts, specific to proposed project site
- Impacts to Coastal Resources (possibly from Environmental Assessment) for current conditions and changes due to sea-level rise and related impacts
    - Public Access and Recreation
        - Show access resources and future changes (site maps)
    - Water Quality, surface and groundwater
        - Provide surface drainage patterns and runoff and future changes (site maps)
        - Provide zone of groundwater elevation
    - Coastal Habitats
        - Provide wetland Delineation, ESHA determination, if appropriate
        - Provide boundary determinations or State Lands review, if appropriate
        - Show all coastal habitats and future changes (site maps)
    - Agricultural Resources
        - Show agricultural resources and future changes (site maps)
    - Natural Landforms
        - Show all natural landforms and future changes (site maps)
    - Scenic Resources
        - Show views from public access and future changes due to access changes
    - Archeological and Paleontological Resources
        - Show archeological/paleontological resources and future changes (site maps)
    - Overlay all Coastal Resources to Establish Areas Suitable for Development (site maps)
- Analysis of Proposed Project and Alternatives
    - Provide Design Amount of Sea Level
    - Provide analysis of the proposed project and alternatives
    - Identify proposed current and future adaptation strategies
    - Show avoidance efforts (site map)
    - Identify hazard minimization efforts that avoid resource impacts (site maps)

Example for Addressing Sea-Level Rise in Coastal Development Permits

Three case studies have been developed as examples of how to include sea-level rise considerations into the CDP process. The three sample projects are a wetland restoration project, a new bluff-top residential development, and a new wastewater treatment facility. These three examples will follow each of the recommended CDP steps, showing how the guidance could be applied in specific situations.

Step 1: Establish the projected sea-level rise range for the proposed project

- *Wetland Restoration Project:* If wetland restoration efforts are intended as mitigation for a development project, the lifetime for the wetland restoration should be at a minimum, the same as the lifetime of the development project, and sea-level rise ranges should be projected for the time period. For wetland restoration projects in which the desired outcome is the protection of the wetland in perpetuity, sea-level rise ranges should be projected over a minimum of 100 years, with consideration for ongoing adaptive management.
- *Bluff-top Residential Development:* The lifetime of the project is assumed to be at least 75 years. High and low sea-level rise projection ranges are established, appropriate for the proposed area over the assumed 75-year project life.
- *Wastewater Treatment Facility:* Wastewater treatment facilities are normally critical infrastructure. For this example a minimum life of 100 years is assumed. High and low sea-level rise projections ranges are established, appropriate for the proposed area over the assumed 100-year project life.

Step 2: Determine how impacts from sea-level rise may constrain the project site

- *Wetland Restoration Project:* Current topography of the wetland area is mapped, current barriers to inland migration are identified, and an analysis of erosion and flooding potential (and subsequent effects to wetland extent) is performed for various sea-level rise scenarios. Potential changes to groundwater are evaluated. Potential changes in sediment flows or other physical properties as a result of changing conditions are examined. It is determined that open space exists behind the wetland to allow for inland migration over time.
- *Bluff-top Residential Development:* The average long-term bluff retreat rate, erosion rate due to various sea-level rise scenarios, and erosion potential from 100-year storms and other extreme events are determined. The geologic stability of the bluff over the life of the development is analyzed assuming that no protective structure (such as a seawall) will be built.
- *Wastewater Treatment Facility:* Erosion and flooding potential over the lifetime of the facility under both a low and a worst-case scenario sea-level rise projection are analyzed, as are current and future wave run-up and storm impacts for 100-year storms. The geologic stability of the site over the life of the facility is analyzed assuming that no protective structure will be built. Potential damage to infrastructure (for example corrosion due to salt water intrusion) is examined.

Step 3: Determine how the project may impact coastal resources, considering the influence of sea-level rise upon the landscape over time

- *Wetland Restoration Project:* Coastal resources present in the proposed project site are mapped and sea-level rise impacts to these resources are analyzed over the lifetime of the project. It is unlikely that the project will have any adverse impact on coastal resources. Barriers to wetland migration are examined and, it is determined that enough open space currently exists to allow for the wetland to migrate inland over time. The few barriers that exist can be modified in the future, if necessary. This will allow for the continued maintenance of habitat area and other ecosystem services.
- *Bluff-top Residential Development:* Maps that identify scenic overlooks, the bluff extent, and adjacent coastal habitats including the fronting beach are developed, and descriptions of each are provided. Opportunities for public access are identified. Impacts to each of these resources as a result of sea-level rise are analyzed, as are impacts that would result from the development project. It is determined that the development has the potential to disturb natural migration of a fronting beach if a protective structure is needed. However, no such structure is planned over the lifetime of the development under any sea-level rise scenario.
- *Wastewater Treatment Facility:* Maps are developed that identify coastal resources in the area and impacts to these resources resulting from sea-level rise are analyzed. As with the bluff-top development, any protective structure would have detrimental effects to the fronting beach, but no such structure is determined to be necessary. Any potential impacts to adjacent habitat areas or to water quality as a result of damage to infrastructure (for example sewage outflow or backup of seawater into the system) are examined under the range of sea-level rise projections for the life of the facility.

Step 4: Identify project design alternatives that avoid resource impacts and minimize risks to the project

- *Wetland Restoration Project:* There are no concerns related to detrimental impacts to coastal resources as a result of this project. Natural barriers will be removed through grading and contouring of the land to ensure that the wetland has the ability to migrate inland with sea-level rise and that hydrologic function will be maintained. Inland areas are protected into the future to ensure the space will be open for migration. Additionally, a plan is included to monitor changes in sea-level, sediment dynamics, and overall health of the wetland so that changes can be made as needed.
- *Bluff-top Residential Development:* The optimal site for a bluff-top residential development is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative sites should be identified and examined. If no such site exists, efforts should be made to minimize hazards and impacts to resources. Minimization efforts may include: building with an extra setback from the bluff-face, developing a managed retreat plan, and designing buildings to be easily relocated. A plan to monitor rates of erosion at various places along the bluff as well as any

impacts to adjacent resources is developed, and erosion rates/scenarios that would trigger the need for retreat are identified.

- *Wastewater Treatment Facility:* The optimal site for a wastewater treatment facility is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative sites should be identified and examined. If no such site exists, efforts should be made to minimize hazards and impacts to resources. Minimization efforts may include: building the facility further back from the beach, elevating outflow pipes, and adding one-way valves to prevent backflow of sea-water into the system. A plan to monitor erosion rates along the beach as well as wave and storm impacts and any impacts to coastal resources caused by the facility is developed.

Step 5: Finalize project design and submit CDP application

- *Wetland Restoration Project:* The best site and design option is chosen and presented to the Commission or local government for the permit process.
- *Bluff-top Residential Development:* The best site and design option is chosen and presented to the Commission or local government for the permit process.
- *Wastewater Treatment Facility:* The best site and design option is chosen and presented to the Commission or local government for the permit process.

VI. ADDITIONAL RESEARCH NEEDS

During the process of creating this guidance document, the Coastal Commission staff identified areas where additional research is needed to help understand and prepare for sea-level rise. The research needs are directed toward research institutions at academic, state, federal, and local levels. The Commission will strive to collaborate with and support research related to sea-level rise science and adaptation.

1. **Improved estimates of local vertical land motion.** Several independent processes – glacial isostatic rebound, groundwater withdrawals, plate movements and seismic activity – influence vertical land motion. Current guidance on sea level projections adjusts for large-scale vertical land motion north and south of Cape Mendocino. These adjustments do not properly address locations that are moving differently from the region, such as Humboldt Bay. A peer-reviewed methodology is needed to determine:
    a. Instances when it will be important to modify the regional sea-level rise projections for local vertical land motion,
    b. Types of existing information on land motion (tide gauge records, satellite data, land-based GPS stations, etc.) that provide the best estimates of local land trends,
    c. A procedure for adjusting state or regional sea-level rise projections for sub-regional or local conditions, and
    d. Additional data that are needed to implement this procedure.

2. **Analysis of sea-level rise impacts to coastal access and recreation.** To improve public access planning efforts, more information is needed about how sea-level rise could affect public access areas and recreation throughout the state, including changes to waves and surfing, and the potential economic costs of these impacts. Many currently accessible beach areas have the potential to become inaccessible due to impacts from sea-level rise. Shoreline armoring and emerging headlands could isolate connected beaches with sea-level rise, which will block lateral access. Rising sea level will also tend to constrict beaches that are prevented from migrating landward by shoreline armoring and development. Some blufftop trails will become inaccessible as segments of trail are lost to erosion. In addition, changes in beach conditions due to sea-level rise could affect waves and surfing. Research on the specifics of these impacts will help the Commission and others understand the details of the potential impacts to coastal access and recreation.

3. **Methods to evaluate impacts to coastal resources from shoreline protection.** Research is needed to develop and improve methods to evaluate and mitigate for the adverse impacts to recreation, public access and beach ecology from shoreline armoring projects. This information will be used to determine a set of mitigation options that may be considered for use when evaluating individual permit applications to offset anticipated losses to beach ecology and resources caused by shoreline armoring projects. The Coastal Commission staff is currently working on developing resource valuation guidelines as part of a Project of Special Merit (see Next Steps, Additional Items).

4. **Analysis of sea-level rise impacts to wetlands and strategies for preserving wetlands throughout the state.** Additional research is needed to assess the vulnerability of wetlands

and other sensitive habitat areas to climate change, and to identify adjacent areas that may be important for future habitat migration (e.g. wetland transitional areas). Further work is also needed to develop management strategies that are adaptable to local wetland conditions and sea-level rise impacts, such as the following:

a. Methodologies for establishing natural resource area buffer widths in light of sea-level rise,
b. Approaches for identifying and protecting migration corridors,
c. Guidance for increasing wetland sediment supply and retention,
d. Techniques for developing an adaptive wetland restoration plan, and
e. Monitoring criteria.

5. **Assessment of coastal habitat vulnerability to sea-level rise and other climate change impacts.** In addition to research on wetland migration potential, further research is needed to identify the coastal habitats that are most likely to experience adverse impacts from sea-level rise and extreme storms. Research is also needed to identify strategies to ameliorate the vulnerabilities.

6. **Baseline data and monitoring of sea-level rise impacts**. Baseline monitoring data is needed for coastal and near-shore waters, beaches, bluffs, dune systems, near-shore reefs, tide pools, wetlands, and other habitat areas to better understand these systems, monitor trends and detect significant deviations from historic conditions that may be related to sea-level rise and other aspects of climate change.

7. **Methods for estimating change in erosion rates and shoreline change due to future sea-level rise.** There is a need for a peer-reviewed methodology for estimating change in erosion rates due to sea-level rise for bluffs, beaches, and other shorelines exposed to erosion.

8. **Potential effects of sea-level rise on coastal aquifers.** Additional research is needed to quantify the potential effect of sea-level rise on freshwater aquifers located along the California coast, and the degree to which sea-level rise could lead to new incidences of intrusion. Research on aquifers should include: (a) an evaluation of the potential incidence and severity of saltwater intrusion at the scale of individual aquifers, under various sea-level rise scenarios, and (b) criteria to use when deciding if saltwater intrusion requires mitigation or response.

VII. NEXT STEPS

The Commission recently completed a Strategic Plan for 2012-2018 and identified many action items that the Commission staff or partner organizations plan to take to address the challenges of sea-level rise and climate change. The first priority in the Plan is to for the Commission to adopt sea-level rise policy guidance for use in LCP planning and project design (3.1.1), and this draft guidance reflects significant progress toward accomplishing this task.

The objectives and action items from the Strategic Plan related to sea-level rise and climate change are listed below, followed by additional items that staff identified as next steps during the completion of this guidance document. These next steps are intended for the Commission staff to complete over the next two to five years, in coordination with other relevant partners and research institutions, as staff capacity and funding allows.

STRATEGIC PLAN EXCERPTS: ACTIONS RELATED TO SEA-LEVEL RISE AND CLIMATE CHANGE

GOAL 1: Maximize Public Access and Recreation

Objective 1.1 – Enhance Public Access through Updated Beach Access Assessment and Constraints Analysis

Actions:

1.1.5 Identify locations where access may be limited or eliminated in the future due to sea-level rise and increased storm events and begin planning for other options such as new vertical accessways to maintain maximum beach access (see also Action 3.2.1).

Objective 1.4 – Expand the California Coastal Trail System through Enhanced Planning and Implementation

Actions:

1.4.4 Identify locations of the CCT that might be at risk from rising sea level and increased storm events and begin planning for trail relocations or other alternatives to insure continued functionality of the CCT (see also Action 3.2.1).

GOAL 3: Address Climate Change through LCP Planning, Coastal Permitting, Inter-Agency Collaboration, and Public Education

Objective 3.1 – Develop Planning and Permitting Policy Guidance for Addressing the Effects of Climate Change on Coastal Resources

Actions:

3.1.2 Adopt general sea-level rise (SLR) policy guidance for use in coastal permitting and LCP planning and amendments based on best available science, including the final report from the Natural Research Council of the National Academy of Science entitled, *Sea-LevelRise for the Coasts of California, Oregon, and Washington* (released June 2012)

3.1.3 Based on the general SLR policy guidance, identify and develop specific regulatory guidance for addressing coastal hazards, including recommendations for analytic methods for accounting for SLR and increased storm events in project analysis, standards for redevelopment and development in hazard zones (e.g. bluff top and flood zones), buffers for coastal wetlands, and policies for shoreline structure design and impact mitigation.

3.1.4 Develop work program to produce policy guidance for coastal permitting and LCPs to account for other climate change related impacts and adaptation planning including wetland, marine and terrestrial habitat protection, habitat migration, risk of wildfires, water supply and groundwater protection, etc.

3.1.5 Provide public information and guidance through workshops, presentations to local government, etc. Assist local governments with interpretation of scientific or other technical information related to climate change and sea level rise that could be of use in adaptation planning.

3.1.6 Contribute to relevant state-wide efforts on climate change and adaptation as a member of the State's Climate Action Team – Coast and Ocean Working Group.

3.1.7 Coordinate with Natural Resources Agency, Office of Planning and Research, California Emergency Management Agency and others to provide consistent guidance on climate change in updating general plans, hazard mitigation plans and other planning documents used by local governments

3.1.8 Coordinate with the State Lands Commission to address sea level rise and shoreline change and implications for the management of public trust resources.

Objective 3.2 – Assess Coastal Resource Vulnerabilities to Guide Development of Priority Coastal Adaptation Planning Strategies

Actions:

3.2.1 Conduct a broad vulnerability assessment of urban and rural areas to identify priority areas for adaptation planning, such as community development, public infrastructure, public accessways, open space or public beaches at risk from sea level rise. Identify and participate in on-going vulnerability assessments and adaptation planning efforts as feasible.

3.2.2 Work with Caltrans and other public agency partners to assess and address roadway, rail, and other transportation infrastructure vulnerabilities, particularly along Highway One and other coastal roads and highways.

3.2.3 Work with the Department of Water Resources, SWRCB and local agencies to assess and address water and wastewater treatment plant vulnerabilities along the coast.

3.2.4 Work with the Conservancy, CDFG, US Fish and Wildlife (USFWS) and other partners to assess the vulnerability of wetlands and other sensitive habitat areas. Identify habitats that are particularly vulnerable climate change and/or habitats that may be important for future habitat migration (e.g. wetland transitional areas).

3.2.5 Work with the Coastal Observing Systems, researchers, and others to identify and develop baseline monitoring elements to better understand and monitor changes in coastal conditions related to sea level rise and other climate change impacts.

3.2.6 With the Conservancy and OPC, develop and implement a competitive grant program to provide funding to selected local governments to conduct vulnerability assessments and/or technical studies that can be used to assess a community's risks from climate change and inform updates to LCPs.

Additional Items:

- **Continue an active program of public information on sea-level rise.** The Commission will strive to provide public information about sea-level rise issues through public workshops, the Commission's web site, meetings, outreach and our public education program.

- **Develop methods for quantifying impacts to coastal resources from shoreline armoring projects.** The Coastal Commission staff has initiated a Project of Special Merit to build upon the Commission's existing efforts to mitigate for the adverse impacts of shoreline development projects to public access and recreation by working with beach ecologists and a valuation economist to develop a method to quantify impacts to biological resources and beach ecology. The final product will be a complete a set of guidelines to use in assessing the impacts of proposed shoreline armoring projects and a method(s) for calculating the full value of recreational and ecological loss resulting from installation of shoreline armoring projects (where they may be approved as consistent with the Coastal Act).

- **Consider producing additional guidance documents, including**:
    - Broader climate change guidance addressing other climate change impacts to the coastal zone.
    - Guidance on managed retreat of critical infrastructure, including when to consider managed retreat rather than continue with repairs and maintenance in light of sea-level rise.
    - One-page fact sheets on some adaptation measures such as green infrastructure, conservation easements, etc.

- Guidance on the use of 'living shorelines' for California, including an assessment of areas or coastal situations where they could be effective, what they need to succeed, monitoring requirements, and maintenance, etc.

VIII. GLOSSARY

The following terms were collected from the 2009 California Climate Change Adaptation Strategy, the Intergovernmental Panel on Climate Change Third Assessment Report (2001), the Coastal Commission's Beach Erosion and Response (BEAR) document,[23] and the California Coastal Act, unless otherwise noted. Some of these definitions are not used in the text of the report, but are included as a resource on coastal-related adaptation issues.

Aquifer: an underground layer of porous rock, sand, or other earth material containing water, into which wells may be sunk.

Armor: to fortify a topographical feature to protect it from erosion (e.g., constructing a wall to armor the base of a sea cliff).

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.

Adaptive Capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[24]

Adaptive Management: Adaptive management involves monitoring the results of a management decision, and updating actions as needed and as based on new information and results from the monitoring.

Baseline/Reference: The baseline (or reference) is any datum against which change is measured. It might be a "current baseline," in which case it represents observable, present-day conditions. It might also be a "future baseline", which is a projected future set of conditions excluding the driving factor of interest (e.g., how would a sector evolve without climate warming). It is critical to be aware of what change is measured against which baseline to ensure proper interpretation. Alternative interpretations of the reference conditions can give rise to multiple baselines.[25]

Beach: the expanse of sand, gravel, cobble or other loose material that extends landward from the low water line to the place where there is distinguishable change in physiographic form, or to the line of permanent vegetation. The seaward limit of a beach (unless specified otherwise) is the mean low water line.

Beach nourishment: placement of sand on a beach to form a designed structure in which an appropriate level of protection from storms is provided and an additional amount of sand (advanced fill) is installed to provide for erosion of the shore prior to the anticipated initiation of a subsequent project. The project may include dunes and/or hard structures as part of the design.

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[23] Many of these definitions were extracted from: U.S. Army Corps of Engineers, 1984; Griggs et al. 1985, California Department of Boating and Waterways and San Diego Association of Governments, 1995
[24] UK CIP 2003.
[25] Moser 2008.

Bluff (or cliff): a scarp or steep face of rock, weathered rock, sediment or soil resulting from erosion, faulting, folding or excavation of the land mass (Figure 15). The cliff or bluff may be simple planar or curved surface or it may be steplike in section. For purposes of (the Statewide Interpretive Guidelines), "cliff" or "bluff" is limited to those features having vertical relief of ten feet or more and "seacliff" is a cliff whose toe is or may be subject to marine erosion.

Bluff top retreat (or cliff top retreat): the landward migration of the bluff or cliff edge, caused by marine erosion of the bluff or cliff toe and subaerial erosion of the bluff or cliff face.

Climate Change: Climate change refers to any long-term change in average climate conditions in a place or region, whether due to natural causes or as a result of human activity.

Impact Assessment: The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Climate Variability: Climate variability refers to variations in the mean state of the climate and other statistics (such as standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond that of individual weather events.

Coastal-dependent development or use: any development or use which requires a site on, or adjacent to, the sea to be able to function at all (from Public Resources Code Section 30101).

Coastal-related development: any use that is dependent on a coastal-dependent development or use (from Public Resources Code Section 30101.3).

Ecosystem-Based Management: Ecosystem-Based Management (EBM) is an integrated approach to resource management that considers the entire ecosystem, including humans, and the elements that are integral to ecosystem functions (National Ocean Council 2011).

Emissions Scenarios: Scenarios representing alternative rates of global Green House Gas (GHG) emissions growth, which are dependent on rates of economic growth, the success of emission reduction strategies, and rates of clean technology development and diffusion, among other factors (Bedsworth and Hanak, 2008).

Environmentally sensitive area: any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments (from Public Resources Code Section 30107.5).

Erosion: the wearing away of land by natural forces. On a beach, the carrying away of beach material by wave action, currents or the wind.

Eustatic: refers to worldwide changes in sea level.

Greenhouse gases: Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit long-wavelength radiation are essential to maintaining the temperatures of the Earth in habitable ranges. The most common greenhouse gases are water vapor, carbon dioxide, methane, ozone and nitrous oxides. Carbon dioxide is the major anthropogenic greenhouse gas and all greenhouse gases are often quantified collectively by their carbon dioxide equivalency, or the amount of CO2 that would have the same global warming potential (GWP), when measured over a specified time period (modified from Wikipedia).

Local coastal program: a local government's (a) land use plans,(b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of, this division at the local level (from Public Resources Code Section 30108.6).

Mean Sea Level: Mean sea level is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides. Relative sea level is sea level measured by a tide gauge with respect to the land upon which it is situated. See Sea level change/sea-level rise.

Mitigation (As used in climate science): A set of policies and programs designed to reduce emissions of greenhouse gases (From Luers and Moser, 2006).

Mitigation (As used in resource management): projects or programs intended to offset known impacts to an existing historic or natural resource such as a stream, wetland, endangered species, or archeological site.

Monitoring: systematic collection of physical, biological, or economic data or a combination of these data on a project in order to make decisions regarding project operation or to evaluate project performance.

Permit: any license, certificate, approval, or other entitlement for use granted or denied by any public agency which is subject to the provisions of this division (From Public Resources Code Section 30110).

Potential Impacts: All impacts that may occur given a projected change in climate, without considering adaptation.

Public Trust Lands: Public Trust lands shall be defined as all lands subject to the Common Law Public Trust for commerce, navigation, fisheries, recreation, and other public purposes. Public Trust Lands include tidelands, submerged lands, the beds of navigable lakes and rivers, and historic tidelands and submerged lands that are presently filled or reclaimed and which were subject to the Public Trust at any time. (From Public Resources Code 13577; see **tidelands** and **submerged lands**.)

Radiative forcing: As used by the IPCC, "Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.

In this report radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2)" (IPCC (2007) Climate Change Synthesis Report; http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf).

Risk: is the possibility of interaction of physically defined hazards with the exposed systems. Risk is commonly considered to be the combination of the likelihood of an event and its consequences – i.e., risk equals the probability of climate hazard occurring multiplied the consequences a given system may experience (UNDP 2005).

Sea level: the height of the ocean relative to land; tides, wind, atmospheric pressure changes, heating, cooling, and other factors cause sea-level changes.

Sea level change/ sea-level rise: Sea level can change, both globally and locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass of water and (iii) changes in water density. Factors leading to sea-level rise under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. See also Mean Sea Level, Thermal expansion (From IPCC 2007).

Sea-level rise impact: An effect of sea-level rise on the structure or function of a system (Pew Center on Global Climate Change 2007).

Sediment: grains of soil, sand, or rock that have been transported from one location and deposited at another.

Sediment Management: is the system-based approach to the management of coastal, nearshore and estuarine sediments through activities that affect the transport, removal and deposition of sediment to achieve balanced and sustainable solutions to sediment related needs.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).

Shore protection: structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.

Still water level: The elevation that the surface of the water would assume if all wave action were absent.

Storm surge: A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in level due to atmospheric pressure reduction as well as that due to wind stress.

Subsidence: Sinking or downwarping of a part of the earth's surface; can result from seismic activity, changes in loadings on the earth's surface, fluid extraction, or soil settlement.

Tectonic: related to the earth's surface.

Tidal prism: the total amount of water that flows into a harbor or estuary or out again with movement of the tide, excluding any freshwater flow.

Tidal range: difference between consecutive high and low (of higher high and lower low) waters.

Tidelands: Tidelands shall be defined as lands which are located between the lines of mean high tide and mean low tide (from Public Resources Code section 13577; see **Public Trust Lands**).

Tsunami: a long period wave, or seismic sea wave, caused by an underwater disturbance such as a volcanic eruption or earthquake. Commonly misnamed a "Tidal Wave."

Vulnerability: the extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.

Vulnerability Assessment: A practice that identifies who and what is exposed and sensitive to change and how able a given system is to cope with extremes and change. A vulnerability assessment considers the factors that expose and make people or the environment susceptible to harm and accesses to natural and financial resources available to cope and adapt, including the ability to self-protect, external coping mechanisms, support networks, and so on (Tompkins et al. 2005).

Wave: a ridge, deformation, or undulation of the surface of a liquid. On the ocean, most waves are generated by wind and are often referred to as wind waves.

Wave height: the vertical distance from a wave trough to crest.

Wave length (wavelength): the horizontal distance between successive crests or between successive troughs of waves.

Wave period: the time for a wave crest to traverse a distance equal to one wavelength, which is the time for two successive wave crests to pass a fixed point.

Wave run-up: the distance or extent that water from a breaking wave will extend up a beach or structure.

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APPENDICES

CONTENTS

APPENDIX A. SEA-LEVEL RISE SCIENCE AND PROJECTIONS FOR FUTURE CHANGE

A.1. Global Drivers of Sea-Level Rise

The main mechanisms driving increases in global sea level are: 1) expansion of sea water as it gets warmer (thermal expansion) and 2) increases in the amount of water in the ocean from melting of land-based glaciers and ice sheets as well as human-induced changes in water storage and groundwater pumping (Chao et al., 2008; Wada et al., 2010; Konikow, 2011).[26] The reverse processes can cause global sea level to fall.

A.2. Local Drivers Sea-Level Rise

Sea level at the regional and local levels often differs from an average global sea level.[27] The primary factors influencing local sea level include tides, waves, atmospheric pressure, winds, vertical land motion and short duration changes from seismic events, storms, and tsunamis. Other determinants of local sea level include changes in the ocean floor (Smith and Sandwell, 1997), confluence of fresh and saltwater, and proximity to major ice sheets (Clark et al., 1978; Perette et al., 2013).

A.3. Factors Influencing Sea-Level Rise in California

As described above, sea-level rise will vary locally and regionally. Over the long-term, sea level trends in California have generally followed global trends (Cayan et al., 2009; Cayan et al. 2012). The 2012 "Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment" from the California Climate Change Center, assumes "that sea-level rise along the Southern California coast will be the same as the global estimates" (Cayan et al., 2012). The 2011 OPC Interim Guidance on Sea-Level Rise also applied global sea level projections to coastal California, recommending specifically that state agencies consider projections of sea-level rise developed from recent semi-empirical global sea level projections (Vermeer and Rahmstorf, 2009).

However, global projections do not account for California's regional water levels or land level changes. California's water levels are influenced by large-scale oceanographic phenomena such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), which can increase or decrease coastal water levels for extended periods of time. Figure 7 shows how El Niño and La Niña events have corresponded to mean sea level in California in the past. California's land levels are affected by plate tectonics and earthquakes. Both the changes to water levels and changes to land level are important factors in regionally down-scaled

[26] Large movements of the tectonic plates have been a third major mechanism for changes in global sea level. The time periods for plate movements to significantly influence global sea level are beyond the time horizons used for even the most far-reaching land use decisions. Plate dynamics will not be included in these discussions of changes to future sea level.
[27] For further discussion of regional sea level variations and regional sea-level rise projections, see, for example, Yin et al. 2010, Slangen et al. 2012, Levermann et al. 2013.

projections of future sea level. For these reasons, sea-level rise projections specific to California are more relevant to projects in the coastal zone of California than projections of global mean sea level.

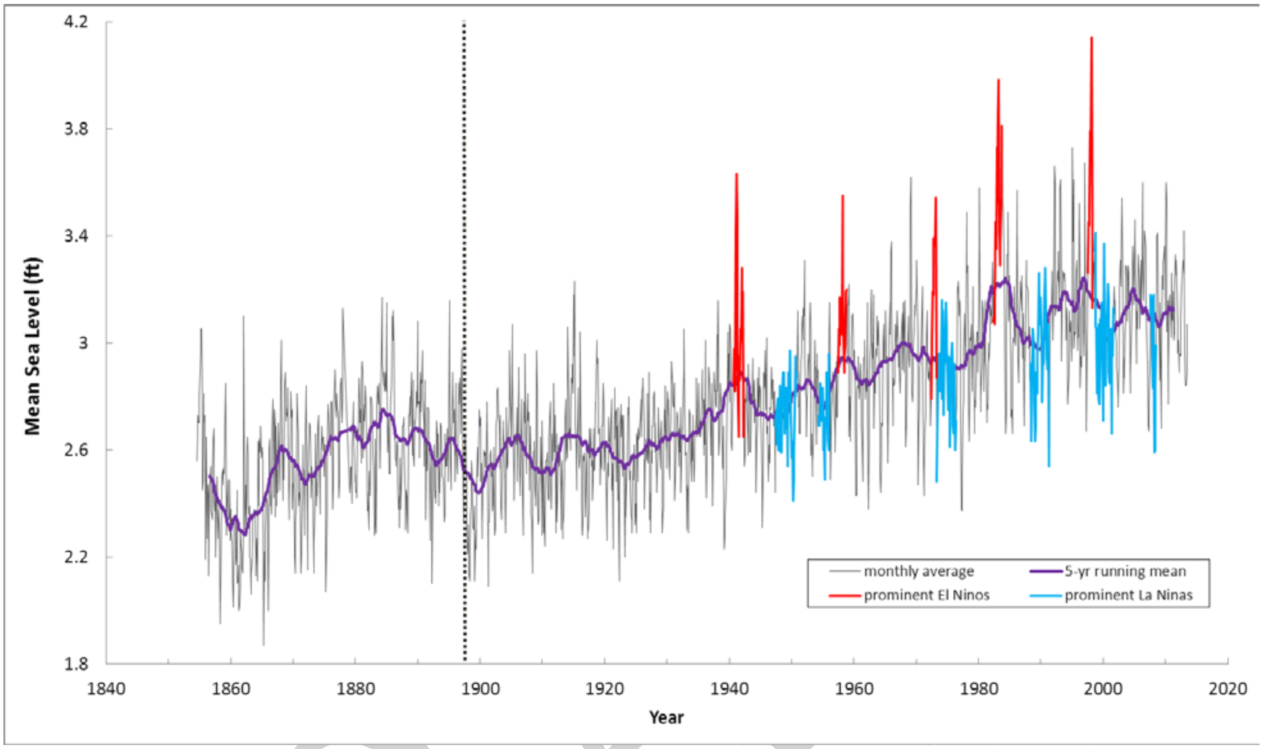

Figure 7. Variations in monthly mean sea level, Fort Point, San Francisco, 1854 to 2013. Mean sea level heights (in feet) are relative to mean lower low water (MLLW). Purple line represents the 5-year running average. Note that the monthly mean sea level has varied greatly throughout the years and the several of the peaks occurred during strong El Niño events (red highlight). Periods of low sea level often occurred during strong La Niña events (blue highlight). The current "flat" sea level condition can also be seen in the 5-year running average. Sources: NOAA CO-OPS data, Station 9414290, http://tidesandcurrents.noaa.gov/ (sea level); NOAA Climate Prediction Center, http://www.elnino.noaa.gov/ (ENSO data).

A.4. Approaches for Projecting Future Global Sea-Level Rise

This section provides an overview of some of the more well-known approaches that have been used to project sea level changes and their relevance to California. Appendix B will cover how these projections can be used to determine water conditions at the local scale.

There is no single, well-accepted technique for projecting future sea-level rise. Understanding future sea-level rise involves projecting future changes in glaciers, ice sheets, and ice caps, as well as future ground water and reservoir storage. Two subjects in particular present challenges in sea-level rise modeling. First, future changes to glaciers, ice sheets, and ice caps are not well understood and, due to the potential for non-linear responses from climate change, they present many difficulties for climate models (Overpeck, 2006; Pfeffer et al., 2008; van den Broecke et al., 2011; Alley and Joughin, 2012; Shepherd et al., 2012; Little et al., 2013). Second, the actual magnitudes of the two human-induced changes – pumping of groundwater and storage of water in reservoirs – are poorly quantified, but the effects of these activities are understood and can be modeled (Wada et al., 2010). Despite these challenges, sea-level rise projections are needed for many coastal management efforts and scientists have employed a variety of techniques to model sea-level rise, including:

1. Extrapolation of historic trends;
2. Modeling the physical conditions that cause changes in sea level; and
3. Relating sea level to other climatic conditions that can be fairly well projected (empirical or semi-empirical method).[28]

There are strengths and weaknesses to each approach, and users of any sea-level rise projections should recognize that there is no perfect approach for anticipating future conditions. This section provides users of the Guidance document with a general understanding of several of the most widely used sea-level rise projection methodologies and their respective pros and cons. For reference, the 2012 NRC Report, which is considered the best available science at present, used a combination of the latter two techniques.

A.4.1. Extrapolation of Historic Trends

Extrapolation of historic trends in sea level has been used for many years to project future changes in sea level. The approach assumes that there will be no abrupt changes in the processes that drive the long-term trend, and that the driving forces will not change. Because drivers of climate change and sea-level rise, such as radiative forcing, are known to be changing, this method is no longer considered appropriate or viable in climate science.

A recent modification to the historic trend method discussed above has been to estimate rates of sea-level rise during the peak of the last interglacial (LIG) period (~125,000 years before present, when some drivers of sea-level rise were similar to those today)[29] based on proxy records and apply those sea-level rise rates to the 21st century. For example, Katsman et al. (2011) and Vellinga et al. (2008) used the reconstructed LIG record of sea level change (from Rohling et al., 2008) to reconstruct sea-level rise rates during rapid climate warming, and applied these rates to estimate sea level at 2100 and 2200. Similarly, Kopp et al. (2009) used sea-level rise rates inferred from the LIG to estimate a range of sea-level rise for 2100 between 1.8 – 3.0 feet (0.56 - 0.92 m). Compared to traditional historic trend extrapolation, this modified approach has the advantage of including the dynamic responses of ice sheets and glaciers to past global climates

[28] Another approach to projecting sea-level rise is to use “expert judgment” (AMAP, 2011; Bamber and Aspinall, 2013). The AMAP 2011 report surveyed the literature to construct a range of estimates of SLR by 2100, and then had a panel of experts decide on a smaller “plausible range”, which not surprisingly falls right in the middle of the ranges shown in Fig. A-1. Bamber and Aspinall (2013) used statistical analysis of a very large number of expert estimates of future SLR to come up with their projected ranges. This approach will not be discussed further in this section.

[29] During the last interglacial, global mean temperature was 1-2ºC warmer than the pre-industrial era (Levermann et al. 2013), while global mean sea level was likely 5 – 9 m above present mean sea level (Kopp et al. 2009; Dutton and Lambeck 2012; Levermann et al. 2013).

that were significantly warmer than the present, but is limited by the large uncertainties associated with proxy reconstructions of past sea level.

A.4.2. Physical Models

Physical climate models use mathematical equations that integrate the basic laws of physics, thermodynamics, and fluid dynamics with chemical reactions to represent physical processes such as atmospheric circulation, transfers of heat (thermodynamics), development of precipitation patterns, ocean warming, and other aspects of climate. Some models represent only a few processes, such as the dynamics of ice sheets or cloud cover. Other models represent larger scale atmospheric or oceanic circulation, and some of the more complex General Climate Models (Climate Models) include atmospheric and oceanic interactions.

The Intergovernmental Panel on Climate Change (IPCC) is one of the main sources of peer-reviewed, consensus-based information on climate change. The IPCC does not undertake climate modeling, but uses the outputs from a group of climate models that project future temperature, precipitation patterns, and sea-level rise, based on specific emission scenarios. Seven of the 16 Models used in the IPCC's 4th Assessment Report (2007)[30] provided projections of sea-level rise, and from these models, the IPCC (2007) projected an increase in average global sea level of 7 inches to 23 inches (18 cm to 59 cm) from the time period of 1980 – 1999 to the time period of 2090 – 2099. However, the IPCC elected not to account for dynamic changes in continental ice volume (glaciers and ice sheets) in its sea level projections, stating, *"Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude."* (IPCC 2007, Table SPM-3). The projections include contributions from ice sheet melt based on historical rates of melt, but do not include estimates of sea-level rise change from increased rates of ice sheet melt because there was only limited understanding of such processes at the time of the report (IPCC 2007). As a result, the IPCC projections from the 4th Assessment Report are thought to underrepresent future sea-level rise.

One outcome from the 2007 IPCC report was the realization that there was a need for focused study and modeling of ice dynamics. As an initial effort to better estimate the contributions of ice flows to sea-level rise, climate researchers and glaciologists attempted to determine the upper limit of possible glacier-melt contributions to sea level over several decades, based on the physical constraints of specific glacier systems. A study by Pfeffer, Harper and O'Neel (2008) looked at the plausibility of a rapid rise in sea level from glacial and possible scenarios of polar ice melt. They determined that discharge rates from Greenland glaciers would need to range from 26.8 to 125 km/yr (16.7 to 78 mi/yr), starting immediately and being sustained through 2100, to cause a 2- or 5-m (6.6 to 16.4 ft) rise in sea level by 2100 (Pfeffer et al., 2008). These rates are larger than ever observed even at peak discharges. The researchers do not dismiss the possibility that this discharge could occur, but conclude, "Although no physical proof is offered that the velocities (for a 2- to 5-meter sea-level rise by 2100) cannot be reached or maintained

[30] The most recent Assessment Report as of the time of this document.

over century scales, such behavior lies far beyond the range of observations and at the least should not be adopted as a central working hypothesis" (Pfeffer et al., 2008, pg. 1342). Pfeffer et al. (2008) also project sea-level rise ranging from about 0.8 to 2.0 m (2.6 to 6.6 ft) by 2100, based on the several scenarios of likely ice flow dynamics. This eustatic rise is based on a 0.3 m (1 ft) rise from thermal expansion and between 0.5 to 1.7 m (1.6 to 5.6 ft) from ice dynamics (Pfeffer et al., 2008). Such analysis indicates the importance of ice dynamics in understanding future sea level change.

Focused research on ice dynamics is underway to improve the ability of climate models to address the scale and dynamics of change to glaciers, ice sheets, and ice caps (e.g., Price et al., 2011; Shepherd et al., 2012; Winkelman et al., 2012; Bassis and Jacobs, 2013; Little et al., 2013). Improved modeling will take time to be developed and tested and new models are not expected to be available for several years.

A.4.3. Semi-Empirical Method

The semi-empirical method for projecting sea-level rise is based on developing a relationship between sea level and some factor (a proxy) –often temperature or radiative forcing– and using this relationship to project changes to sea level. An important aspect of the proxy is that there be fairly high confidence in models of its future changes; a key assumption that is made by this method is that the historic relationship between sea level and the proxy will continue into the future. One of the first projections of this kind was based on the historic relationship between global temperature changes and sea level changes (Rahmstorf, 2007). This semi-empirical approach received widespread recognition with the publication of sea-level rise projections by Rahmstorf (2007). These projections looked at the temperature projections for two of the IPCC emission scenarios that span the likely future conditions within the IPCC framework -- B1, an optimistic, low-GHG emission future and A1FI, a more "business-as-usual" fossil fuel intensive future (See Box on Emissions Scenarios, below).[31] The 2007 projections of sea-level rise were used in the California 2009 Climate Change Scenarios Assessment (Cayan, 2009).

Since the initial semi-empirical projections for future sea-level rise (Rahmstorf, 2007), other researchers have published different projections based on the IPCC scenarios, using different data sets or best-fit relationships.[32] Notably, Vermeer and Rahmstorf (2009) prepared a more detailed methodology that includes both short-term responses and longer-term responses between

[31] When the IPCC began examining climate change, the available models were using a broad range of inputs. In an attempt to evaluate the different model outputs based on the different model characteristics, rather than the inputs, the IPCC developed a number of standard GHG emission scenarios. These scenarios are described in IPCC 1990 Response Strategies Working Group III. In general, the B1 scenario projects the lowest temperature and sea level increases and the A1FI projects the highest increases (IPCC 1990).

[32] Semi-empirical projections of sea-level rise through relationships between water level and radiative forcing such as those from Grinsted et al., 2009, Jevrejeva et al., 2010, Katsman et al. 2011, Rahmstorf et al., 2012, Meehl et al., 2012, Schaeffer et al., 2012 and Zecca & Chiari, 2012 have shown general agreement with the projections by Vermeer and Rahmstorf (2009). The Grinsted et al. projections have a wider range than those from Vermeer and Rahmstorf, while the Jevrejeva et al., projections are slightly lower. All semi-empirical methods project that sea level in 2100 is likely to be much higher than linear projections of historic trends and the projections from the 2007 IPCC.

sea-level rise and temperature. These 2009 projections of sea-level rise were used in the 2010 OPC Interim Guidance on Sea-Level Rise (OPC, 2010) and the California 2012 Vulnerability and Assessment Report (Cayan, 2012).

There are also several new semi-empirical sea-level rise projections based on scenarios other than those developed by the IPCC. For instance, Katsman et al. (2011) use a "hybrid" approach that is based on the one of the newer radiative forcing scenarios and empirical relationships between temperature change and sea level. Future projections were then modified to include contributions from the melting of major ice sheets based on "expert judgment". This yields what they call "high end" SLR projections for 2100 and 2200 under several emissions scenarios.

Zecca and Chiari (2012) produced semi-empirical sea-level rise projections based on their own "fossil fuel exhaustion" scenarios (different scenarios of when fossil fuel resources would be economically exhausted). Though based on a different set of assumptions about human behavior/choices, in terms of global temperature and radiative forcing, the scenarios do not differ greatly from the IPCC scenarios. The results are identified as being "lower bound" sea-level rise projections for high, medium, low fuel use scenarios, and "mitigation" (extreme and immediate action to replace fossil fuel use) scenarios. The report then provides projections for the 2000-2200 time period.

Figure 8 provides a visual summary of several of the more commonly cited projections of future global sea-level rise. The following box provides descriptions of the assumptions used in each of the IPCC AR4 (2007) scenarios.

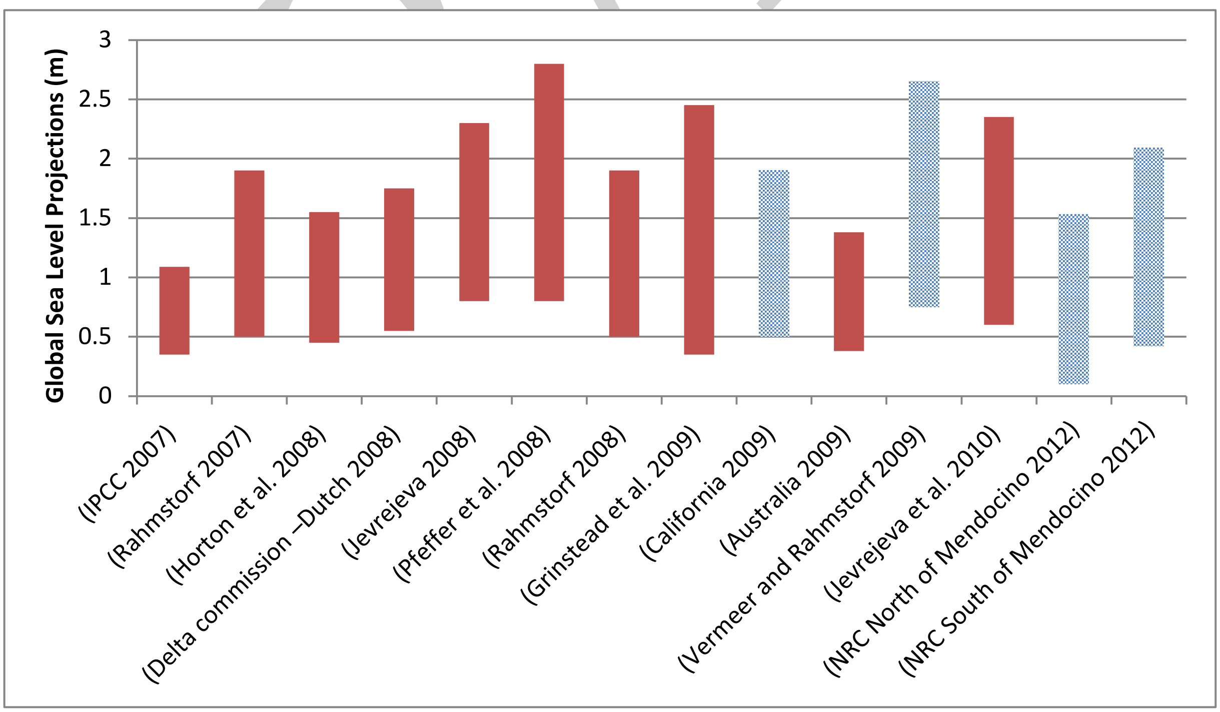

Figure 8. Various 2100 Global Sea-Level Rise Projections. Graphic summary of the range of average global sea-level rise (SLR) projections by end of century (2090–2100) from the peer-

reviewed literature) as compared to the recent National Research Council report for California, Oregon and Washington. The blue patterned boxes indicate projections for California. Ranges are based on the IPCC scenarios, with the low range represented by the B1 scenario (moderate growth and reliance in the future on technological innovation and low use of fossil fuels) and the high part of the range represented by the A1FI scenario (high growth and reliance in the future on fossil fuels). Details on the methods used and assumptions are in the original references.

The Emissions Scenarios of the Special Report on Emissions Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.

The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

(SOURCE: IPCC Special Report on Emissions Scenarios)

A.5. Recent Projections of Sea-Level Rise and Best Available Science on Sea Level

A.5.1. National Projections of Sea-Level Rise

Nationwide, the current best available science on sea-level rise projections is the Global Sea Level Rise Scenarios Report for the United States National Climate Assessment (NOAA, 2012). The report provides a set of four scenarios of future global sea-level rise, as well as a synthesis of the scientific literature on global sea-level rise. The NOAA Climate Program Office produced the report in collaboration with twelve contributing authors.[33] The report includes the following description of the four scenarios:

- **Low scenario:** The lowest sea level change scenario (8 inch rise) is based on historic rates of observed sea level change.
- **Intermediate-low scenario:** The intermediate-low scenario (1.6 feet) is based on projected ocean warming.
- **Intermediate- high scenario:** The intermediate-high scenario (3.9 feet) is based on projected ocean warming and recent ice sheet loss.
- **High scenario:** The highest sea level change scenario (6.6 feet) reflects ocean warming and the maximum plausible contribution of ice sheet loss and glacial melting. This highest scenario should be considered in situations where there is little tolerance for risk (NOAA, 2012).

The NOAA 2012 report provides steps for planners and local officials to modify these scenarios to account for local conditions. These steps are intended for areas where local sea-level rise projections have not been developed. For California, the NRC report (below) provides scenarios that have been refined for use at the local level, and the Coastal Commission, along with the State of California Sea Level Rise Guidance, recommends using the NRC projections rather than the global scenarios.

A.5.2. California-Specific Projections of Sea-Level Rise and Best Available Science

The National Research Council (NRC) Committee on Sea-Level Rise in California, Oregon and Washington (NRC Committee) recently released a report on regional sea-level rise trends and projections of future sea level change for California, Oregon and Washington. This report provides a broad examination of sea level for the California coast and currently represents the best available science on the topic. The NRC Committee investigated both the global and regional sea level projections, taking a different track than earlier efforts to develop sea-level rise projections both globally and for the California coast. The NRC Committee started with several of the basic scenarios that have been the foundation of the IPCC climate projections and the

[33] Authors include NOAA, NASA, the U.S. Geologic Survey, the Scripps Institution of Oceanography, the U.S. Department of Defense, the U.S. Army Corps of Engineers, Columbia University, the University of Maryland, the University of Florida, and the South Florida Water Management District.

earlier climate projections for California. They combined projections of steric changes (thermal expansion or contraction) with changes in the amount of ocean water due to melting of land-based ice on Greenland and Antarctica, as well as contributions from other land-based glaciers and ice caps. Table 5 shows the NRC projections for *global* sea-level rise.

Table 5. Recent Global Sea-Level Rise Projections for 2000 to 2100

Time Period	NRC Report, 2012 (Metric)		NRC Report, 2012 (English)	
	Average	Range	Average	Range
2000 – 2030	13.5 ± 1.8 cm	8.3 – 23.2 cm	5.3 ± 0.7 inch	3.3 – 9.1 inch
2000 – 2050	28 ± 3.2 cm	17.6 – 48.2 cm	11 ± 1.3 inch	6.9 – 19.0 inch
2000 – 2100	82.7 ± 10.6 cm	50.3 – 140.2 cm	32.6 ± 4.2 inch	19.8 – 55.2 inch

Source: NRC, 2012

After developing the global sea-level rise projections, the NRC Committee modified the global projections based on the influence of polar ice and regional changes in uplift and subsidence to create sea-level rise projections for California specifically. The NRC Committee identified distinctly different land level changes north and south of Cape Mendocino. The area north of Cape Mendocino is experiencing significant uplift of about 1.5 to 3 mm/yr (0.059 to 0.118 inches/yr) that the Committee attributed to plate movement along the Cascadia Subduction Zone (NRC, 2012, p. 93). In contrast, the coast south of Cape Mendocino is dropping at an average rate of about 1 mm/yr (0.039 inches/yr) (NRC, 2012, p. 93). The measurements of land subsidence south of Cape Mendocino vary widely, from -3.7 mm/yr to +0.6 mm/yr (-0.146 inches/yr to + 0.024 inches/yr) (NRC, 2012, p. 93), with slightly greater subsidence in southern California than in Central California.[34] The NRC Committee noted that the uplift being experienced along the Cascadia Subduction Zone may reverse during a fault rupture or earthquake of magnitude 8.0 or greater along the Cascadia Subduction Zone. The NRC report notes that during a large earthquake (magnitude 8 or greater), coastal areas could experience sudden vertical land motion, with uplift in some locations and subsidence as much as 6.6 feet (2 meters) in other locations (NRC, 2012). Despite the rapid reversibility of much of the coastal uplift north of Cape Mendocino, the NRC Report provided projections of regional sea level through 2100 that incorporate land uplift. Table 6 shows the regional projections of sea-level rise from the NRC Report.

[34] Personal Communication to staff from Anne Linn, NRC Study Director (August 1, 2012)

Table 6. California Sea-Level Rise Projections for 2000 to 2100

Time Period	NRC Report 2012	
	North of Cape Mendocino[35]	South of Cape Mendocino
2000 – 2030	-4 – +23 cm (1.6 – +9.0 inch)	4 – 30 cm (1.6 – 12 inch)
2000 – 2050	-3 – + 48 cm (-1.0 – +19.0 inch)	12 – 61cm (5 – 24 inch)
2000 - 2100	+10 – +143 cm (+4 – +56 inch)	42 – 167 cm (16.5 – 66 inch)

Source: NRC, 2012.

The NRC report also provides sea-level rise projections for four individual coastal communities that have long-term tide gauge records, including San Francisco and Los Angeles. These projections match the regional projections for south of Cape Mendocino to within a few millimeters, demonstrating that the regional projections track closely with more localized projections. The NRC report provides no information about the appropriate coastal section that might be included with either the San Francisco or Los Angeles projections. Due to the lack of direction about how to use the localized projections and their close fit with the regional values, the NRC scientists recommend using the regional values, with the exception of parts of Humboldt Bay and the Eel River estuary, unless the area in question is very close to either San Francisco or Los Angeles.

A.5.3 Findings from 2012 NRC Report on Natural Shoreline Responses to Sea-Level Rise

Rising sea level will accelerate many of the flooding and erosion conditions that are already putting coastal development and infrastructure at risk. Some of the key findings about impacts to natural shorelines throughout California from the NRC report include:

- **Bluffs and cliffs:** Sea-level rise will lead to an increase in bluff erosion and bluff retreat because more wave energy will be available to erode cliffs and bluffs. Waves will break closer to the coastline and will reach the base of the cliff or bluff more frequently, increasing the rate of retreat. Current responses such as armoring bluffs will be less effective as overtopping occurs more frequently.

- **Beaches:** Sea-level rise will cause landward migration or retreat of beaches over the long term. Beaches with seawalls or other barriers will not be able to migrate landward and the sandy beach areas will gradually become inundated.

- **Coastal dunes:** Sea-level rise will cause dunes to retreat quickly.

[35] With the exception of parts of Humboldt Bay and the Eel River Estuary which are experiencing subsidence and therefore a higher rate of sea-level rise than projected for the region.

- **Changing retreat rate:** The report finds that extrapolation of current erosion rates until 2030 is a reasonable approach. Beyond 2030, the report recommends that an unspecified "safety factor" should be added to existing trends to accommodate future sea-level rise and potential increases in storm wave heights.

- **Estuaries and tidal marshes:** Sea-level rise may affect the tidal dynamics within the estuary, including the tidal range. The transition from intertidal flats to marshes is especially sensitive to changes in sea level, depending on salinity and inundation tolerance limits of vegetation. Marshes will migrate inland if land is available and the marsh is able to build in elevation at a rate that keeps pace with sea-level rise. Estuaries and marshes that have adequate space to migrate can buffer the impacts of sea-level rise to built environments.

- **Coastal sediment supplies:** Supplies of sediment to the coast will be important for survival of wetlands and tidal marshes, and to a lesser extent, of beaches during rising sea level. Through 2050, frequent storms that promote sediment deposition could allow marshes to survive; by 2100 only areas of high sediment supplies may support viable marsh habitat if the higher range of sea level is experienced. In northern California, water management practices will also be important for long-term marsh survival.

APPENDIX B. DEVELOPING LOCAL HAZARD CONDITIONS BASED ON REGIONAL OR LOCAL SEA-LEVEL RISE USING THE NRC 2012 REPORT[36]

Determining local hazard conditions is one of the first steps in sea-level rise planning efforts. Because sea-level rise varies locally, this analysis must be performed on a site-by-site basis, and obtaining data or conducting research at the correct geographical scale is something project applicants and planners should prioritize. The 2012 NRC Report is the best available science on California's regional sea-level rise, and it should be used when sea-level rise projections are needed.

Much of the research by the IPCC and others, and even the material in the 2012 NRC Report, has focused on global and regional changes to mean sea level. However, the coast is formed and changed by local water and land conditions. Tide range influences where beaches, wetlands and estuaries will establish; waves and currents are majors drivers of shoreline change; storms and storm waves are often the major factors causing damage to coastal development. It is local conditions that influence beach accretion and erosion, storm damage, bluff retreat and wetland function.

Local water levels along the coast are affected by local land uplift or subsidence, tides, waves, storm waves, atmospheric forcing, surge, basin-wide oscillations, and tsunamis. Some of these factors, such as tides and waves, are ever-present and result in ever-changing shifts in the local water level. Others, such as storms, tsunamis, or co-seismic uplift or subsidence, are episodic but can have an important influence on water level when they occur. The following section discusses these factors in the context of sea-level rise and how they are incorporated into planning and project analysis.

In most hazard situations, high water will be the main project or planning concern. For wetlands, low and high tides will be of concern and, in some special situations, such as for intake structures, low water might be the main concern. In some situations where low water is the concern, current low water is likely to be the low water planning condition and there may be no need to factor future sea-level rise into those project or planning situations. The following Text Box identifies some of the key situations or indicators that may be important for coastal managers and applicants to consider sea-level rise during project review.

[36] This guidance provides specific direction for using the materials from the 2012 NRC Report. As the best available science for sea-level rise changes, Commission staff will assess whether revisions to this guidance will be needed. Until this is revised, readers should use their best judgment in applying this guidance for other reports. For example, information is provided for developing sea-level rise projections for years other than 2030, 2050, or 2100. If the next report provides projections for different years than 2030, 2050, or 2100, the new projection years can be substituted for the NRC years. If new projections are found to improve the information from the NRC report, the formula for interpolation of the NRC projections should not be used.

General Situations when Sea-Level Rise Analysis Should be Considered

Project or planning site is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding from waves
- Currently in a location protected from flooding by constructed dikes, levees, bulkheads, etc.
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply

For situations where future sea level conditions will be important, the following steps are provided as guidance for determining local hazards. Figure 9 shows the general progression for going from global sea level projections to the possible consequences or impacts that can result from local water levels.

1. **Determine appropriate planning horizon or expected project life.** Determine the appropriate planning horizon or expected project life (which is often provided in the LCP). For many planning efforts, more than one planning horizon may be needed.

2. **Determine regional sea level projections for planning horizon or expected project life.** Select an appropriate regional sea-level rise projection based on the planning horizon or expected project life. For scenario-based planning and project analysis, more than one sea-level rise projection should be used.

3. **Modify regional sea-level rise projections for local vertical land motion:** Modify the regional sea-level rise projection to account for local vertical land motion, if appropriate. In locations with a large discrepancy between the recorded sea level trend and the regional projections (such as Humboldt Bay), modifications of the regional sea-level rise projections will be necessary. In most situations, the values from the NRC Report can be used without modification.

4. **Project tidal elevations and future inundation:** Project future tidal elevations (mean higher high, mean lower low, etc.), based on historic tidal records and the appropriate NRC (2012) sea-level rise projection.

5. **Determine water level changes from surge, El Niños, PDOs, etc.:** Determine projected water level changes from storm surge, atmospheric pressure, the El Niño/Southern Oscillation, the Pacific Decadal Oscillation or other basin-wide phenomena.

6. **Estimate beach, bluff, and dune change from erosion:** Estimate likely future beach erosion and beach scour, or bluff erosion, if bluffs are present, for appropriate planning horizon or expected project life, including if possible, the changes in erosion due to sea-level rise.

7. **Determine potential flooding, wave impacts, and wave runup:** Determine projected wave impacts and wave runup from a 100-year storm event, for planning horizons or expected project life, based on high tide and other water level changes, future beach and bluff erosion and future beach scour.

8. **Examine potential flooding from extreme events:** Examine possible impacts from extreme events, such as storms with return intervals greater than 100 years, tsunamis, etc.

9. **Repeat as necessary:** Repeat for each planning horizon or sea-level rise scenario.

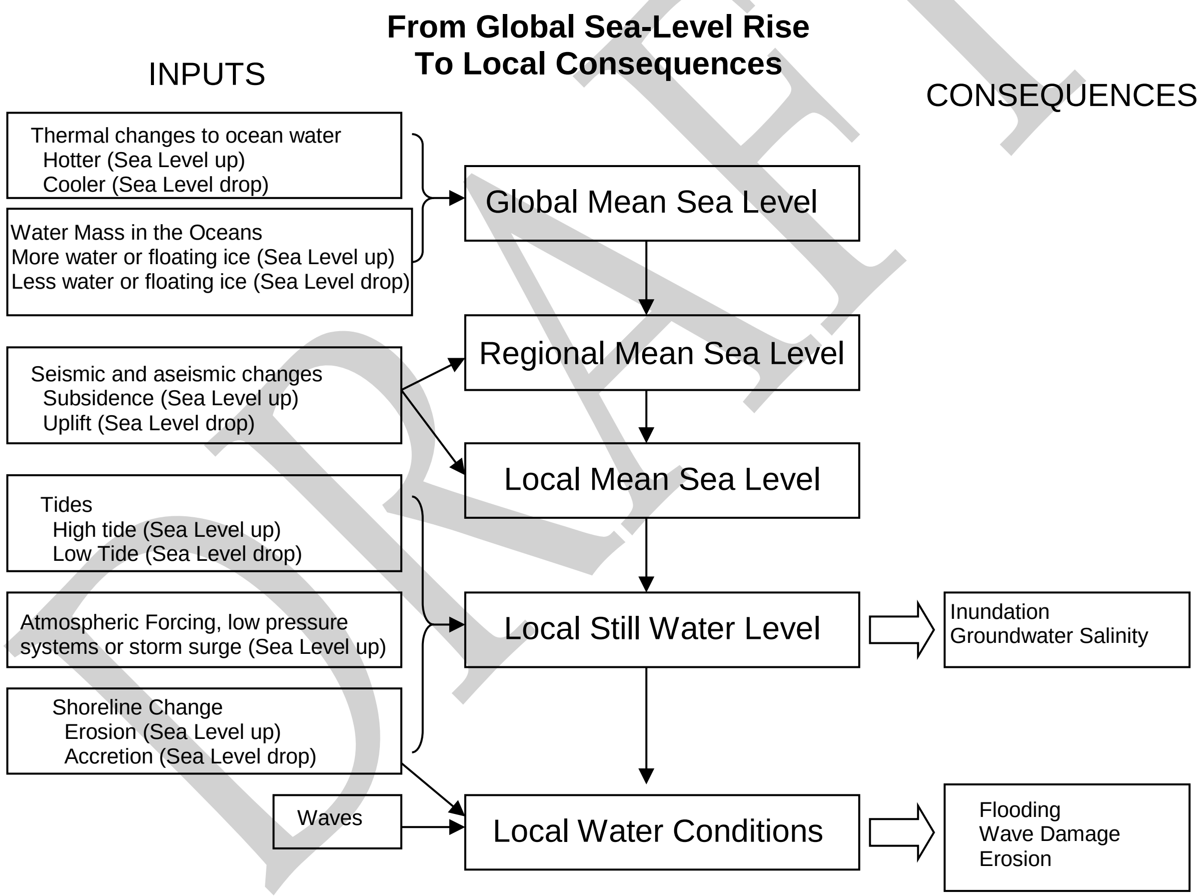

Figure 9. General process for changing global sea-level rise for local conditions.

Step 1 – Determine Appropriate Planning Horizon or Expected Project Life

The first step in a sea-level rise analysis is to determine the appropriate planning horizon or expected life of the project. The longer the life of a project or planning horizon, the greater the amount of sea-level rise the project or planning area will experience. Also, since future sea level is not expected to be linear, the amount of sea-level rise that can be expected to occur over some length of time will increase with a later starting time. For example, a project built today will experience less sea-level rise over a 50-year lifetime (about 24 inches or 61 centimeters using the higher projections for south of Cape Mendocino) than the same project if it were built in the year 2050 (about 40 inches or 101 centimeters, using the higher projections for south of Cape Mendocino). Thus, it is important to understand the projected life of a structure and the planning horizon before starting an analysis for sea-level rise concerns.

Local governments should select their planning horizons to evaluate a broad range of planning concerns. Planning horizons might address the 20-year time period for general plan updates to the long-range planning necessary for infrastructure and new development. At the project level, the LCP can often provide insight into the time period that should be considered for the expected project life. At present, most LCPs provide only a single standard for the expected life of structure or development, normally 50, 75, or 100 years. Future LCPs and LCPAs may find it useful to provide greater guidance on expected project life, with differentiations among major development or use classifications.

Outcome from Step 1: *Step 1 provides an identification of the years and time periods that will be used in analysis of the project or development of a plan*.

Step 2 – Determine Regional Sea Level Projections for Planning Horizon or Expected Project Life

The second step in an analysis of sea-level rise is to determine the regional sea-level rise projections that are appropriate for the proposed project or planning effort. At present, the 2012 NRC report provides the best available science for regional sea-level rise projections. However, these projections are provided as changes in sea level from the year 2000 to 2030, 2050, and 2100. If the planning horizon or expected project life is at or very close to these years, the projections can be used as given. In many cases, these projections will need to be modified to obtain projections for the time periods of interest. There are several modifications that may be appropriate:

- Developing sea-level rise projections for years other than 2030, 2050 or 2100.
- Developing sea-level rise projections for planning or projects with start times other than the year 2000.
- Developing sea-level rise projections for planning or projects with an anticipated life beyond the year 2100.

Guidance for all three situations is provided below.

<u>Projection of sea-level rise for years other than 2030, 2050, and 2100</u>
For sea-level rise projections for years within a few years of those used in the NRC projections, the 2030, 2050, and 2100 projections can be used. However, for years that are not close to these years, sea-level rise projections should be interpolated from the projections. Two methods are recommended for establishing a projection value for a specific year: (1) conduct a linear interpolation[37], or (2) use the "best fit" equations that are provided below. At this time, both are acceptable.

1. Linear Interpolation: One method for establishing a sea-level rise projection for a specific year is linear interpolation between the two known or given projections. The most immediate time periods before and after the desired time period should be used. For example, for a proposed project south of Cape Mendocino with an expected life till 2075, the upper range for the sea-level rise projections closest to this time period are 2.0 feet (61cm) for 2050 and 5.48 feet (167 cm) for 2100.

SLR(2075) = SLR(2050) + ((SLR2100 – SLR2050) x (2075 - 2050/(2100 – 2050))
= 2.0' + ((5.48' – 2.0')(2075 – 2050)/(2100 – 2050)
= 2.0' + ((3.48)(25)/50) = 3.74' (114 cm)

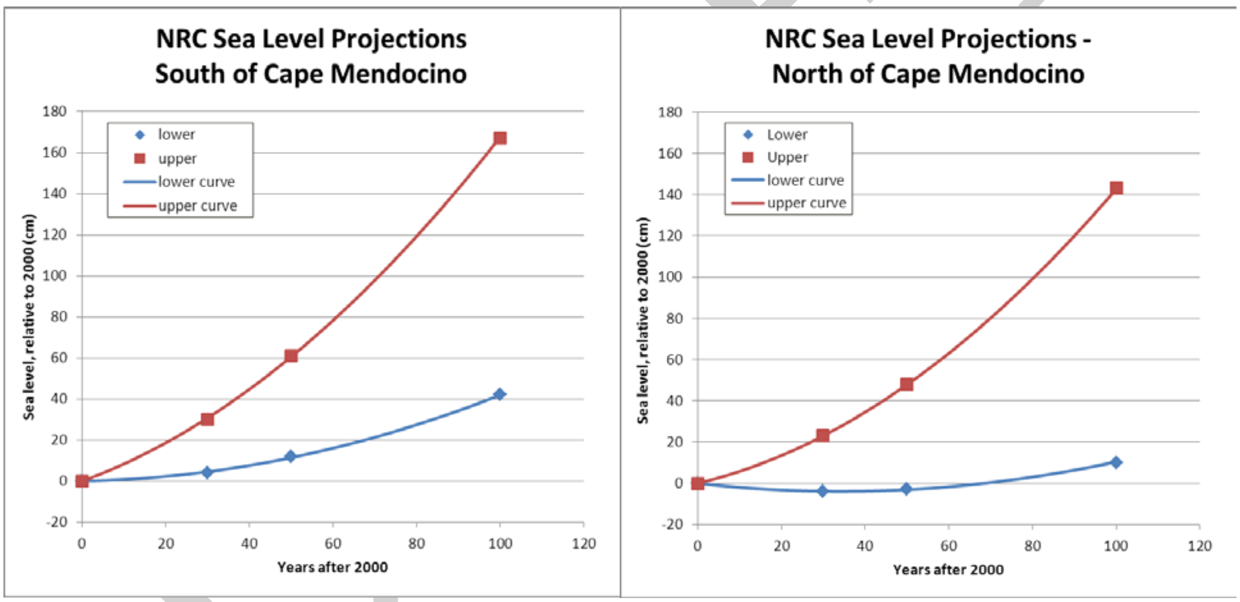

Figure 10. Sea-level Rise Projections, North and South of Cape Mendocino (from NRC Report)

2. <u>Use Equation:</u> A second option is to use one of the following quadratic equations that represent the "best fit" for each of the above sea-level rise curves. These equations can be used to project sea-level rise for years other than 2030, 2050, and 2100. These equations provide sea-level rise in centimeters. If English units are desired, the projections will need to be converted using 1 cm = 0.0328 feet, or 1 cm = 0.394 inches.

[37] Linear interpolation is a method for filling in gaps in data or information that assumes that two known data points that bound the unknown point can be connected with a straight line. The missing information is estimated through reference to this line. The example in the text provides an example of the mathematical steps for linear interpolation.

Equations for Sea-Level Rise Projections, based on values from the NRC Report (NRC 2012)

North of Cape Mendocino

- Upper Range -- Sea Level Change (cm) = $0.0094t^2 + 0.4868t$ (Equation B-1)
- Lower Range – Sea Level Change (cm) = $0.0033t^2 - 0.2257t$ (Equation B-2)

South of Cape Mendocino

- Upper Range – Sea Level Change (cm) = $0.0093t^2 + 0.7457t$ (Equation B-3)
- Lower Range Sea Level Change (cm) = $0.0038t^2 + 0.039t$ (Equation B-4)

Where "t" is the number of years after 2000

For example, if the proposed project were south of Cape Mendocino, with an expected life of 75 years, use Equation B-3, with t = 75.

$$\textit{Sea Level Change (cm)} = 0.0093 \times (75)^2 + (0.7457 \times 75) = 52 + 56 = 108 \text{ cm}$$

The sea level change projected using the equation is slightly less than that projected by linear interpolation because the NRC's sea level curves, shown in Figure 10, are concave upward (sea-level rise is expected to accelerate over the 21st century). A line between any two points on the curve will always be slightly higher than the curve itself.

As noted previously, either method is acceptable for estimating sea-level rise for a year that has not been provided in the NRC Report.

Ranges of sea-level rise projections that do not start at the year 2000

The NRC sea-level rise projections use the year 2000 as the base year. Since there has been little, if any, measureable rise in sea level since 2000 for most locations in California (Bromirski et al., 2011; NOAA Tides and Currents, 2013), there is little reason or justification for adjusting sea-level rise projections from 2000 to a more current start date. All of the latent sea-level rise might occur quickly, providing sea level conditions consistent with the future projections. Thus, when the needed sea level value is a projection of the future sea level that will be experienced by a proposed project for a proposed planning situation, there is no need to adjust the 2012 NRC projections for a different project starting year.

If the needed sea-level rise value is the range of sea level that might be experienced over a future time period, as might be used for planning a wetland restoration project, then adjustments to the starting point for sea-level rise projections may be necessary. Given the recent lack of sea level change in California, it is suggested that such planning or design efforts not do any adjustments to the sea-level rise projections for start dates prior to about 2015 or 2020. When the range of sea level exposure is needed for a future planning scenario, this sea level range can be developed by interpolating the sea level projections for the starting and ending years, and obtaining the difference in sea level by subtracting these two. For example, if a restoration project will be designed to take into account the sea-level rise that will occur from 2040 to 2060, use Equations

B-1, B-2, B-3 or B-4 to get SLR(t1) and SLR(t2) and subtract SLR(T- 40 years) from SLR(t= 60 years) to get the range of sea-level rise from 2040 to 2060.

Sea-level rise projections beyond 2100

Sea-level rise is expected to continue well past the year 2100, despite the termination of most projections at that year.[38] The uncertainty associated with any projections for sea level grows significantly as the time period increases. There are large uncertainties in projections for sea-level rise in the 2100 time period. However, long-term planning and projects requiring long lead times or large capital expenditures need to consider conditions that might occur in the next 100 or more years.

At this time, there are no studies that specifically address projections of sea-level rise for California beyond the year 2100. The NRC projections stop at 2100 and provide no guidance for extrapolation of the range of sea-level rise projections past that time. The equations provided above, while most appropriate for interpolation up to 2100, can be used to extrapolate sea-level rise for a few years beyond 2100. For projections beyond about 2105 or 2110, alternative methods should be considered for developing sea-level rise projections.

1. Use the NRC projections for 2050 and 2100 to develop a linear trend beyond 2100.
2. Use sea-level rise rates that have been developed in recent years, some of which are provided in Table 7.
3. Interpolate between the NRC projections, and one of the reports that provides projections of global sea-level rise for 2200 or 2300 (some of which are listed in Table 8).

None of these options will provide sea-level rise projections that have a confidence similar to the NRC projections. Eventually, there may be regionally appropriate projections for sea level into the 22nd and 23rd centuries. Until then, some assumptions may need to be used for analysis that goes into these time periods. It is clear that sea level will continue to rise past 2100, and any effort to look beyond the year 2100 will be better than using projections of sea-level rise for 2100 as the upper limit of what might happen beyond that time. Nonetheless, it is critical that long-range planning efforts and projects with long design lives include provisions to revisit SLR hazards periodically, and to make adjustments as new science becomes available.

[38] For example, a recent study by Levermann et al. (2013) suggests that, due to slow-acting ice sheet processes and climate feedbacks, global warming of just 2 ºC (at the low end of current projections for the 21st century) would "commit" the planet to between 2.6 – 7.5 meters of sea-level rise over the next 2,000 years.

Table 7. Range of Global Sea-level Rise (from Nichols et al., 2011)

Sea-level rise Feet/century (Meters/century)	**Methodological Approach**	**Source**
1.6 – 4.6 (0.5 – 1.4)	Semi-empirical projection[b]	Rahmstorf 2007
2.6 - 7.9 (0.8 – 2.4)[a]	Paleo-climate analogue	Rohling et al.2008
1.8 – 3.6 (0.55 – 1.10)	Synthesis[b]	Vellinga et al. 2008
2.6 – 6.6 (0.8 – 2.0)	Physical constraints analysis[b]	Pfeffer et al. 2008
1.8 – 3.0 (0.56 – 0.92)[a]	Paleo-climate analogue	Kopp et al. 2009
2.5 – 6.2 (0.75 – 1.90)	Semi-empirical projection[b]	Vermeer & Rahmstorf 2009
2.4 – 5.2 (0.72 – 1.60)[c]	Semi-empirical projection[b]	Grinsted et al. 2009

[a] Higher rates are possible for shorter periods
[b] For the 21st century
[c] For the best paleo-temperature record.

Table 8. Projections of Global Sea-level rise Beyond 2100

Projection Scenario[a]	Sea-level rise for 2300, referenced to 2000 (Schaeffer et al., 2012) ft (m)	2300 Sea-level rise rate (Schaeffer et al., 2012) inches/yr (mm/yr)	Sea-level rise for 2500, referenced to 2000 (Jevrejeva et al., 2012) ft (m)
RCP4.5	7.0 – 17.3 (2.12 – 5.27)	0.24 – 0.74 (6 - 20)	2.4 – 14.1 (0.72 – 4.3)
RCP3PD	3.9 – 10 1 (1.18 – 3.09)	0.04 – 0.35 (1 - 9)	0.4 – 5.7 (0.13 – 1.74)
RCP6			3.4 – 19.0 (1.03 – 5.79)
RCP8.5			7.4 – 37.8(2.26 – 11.51)
Stab 2°C	5.1 – 13.2 (1.56 – 4.01)	0.16 – 0.55 (4 – 14)	
Merge400	2.8 – 7.7 (0.86 – 2.36)	-0.08 – 0.12 (-2 – 3)	
Zero 2016	2.5 – 6.8 (0.76 – 2.08)	0.04 – 0.24 (1 – 6)	

[a] See referenced reports for details on projection scenarios.

Outcome from Step 2: *Step 2 provides a regional sea-level rise projection that can be used to for project analysis or development of a plan.*

<u>Step 3 – Modifying Regional Sea-Level Rise Projections for Local Vertical Land Motion</u>

NOTE: This step is necessary only for project analysis or planning efforts in the vicinity of Humboldt Bay and the Eel River estuary. For all other areas, this step can be skipped.

Changes in land level, either from uplift or subsidence, will affect the sea level measured at that location. Relative sea level, also known as local sea level, is the term used to describe changes to locally measured sea level from land uplift or subsidence (i.e. sea-level rise relative to land change). For land that is subsiding while sea level is rising, the rates are additive such that regional sea-level rise will be the sum of global sea-level rise plus land subsidence. If the land is undergoing uplift, the uplift will cancel out some or all sea-level rise, and regional sea level will be global sea-level rise minus land uplift.

Relative Sea Level Change Rate = Sea-level rise Rate + Land Subsidence Rate

Or

Relative Sea Level Change Rate = Sea-level rise Rate – Land Uplift Rate

The NRC Report has adjusted regional sea level projections for the large-scale uplift and subsidence that has been observed along the coast. However, the NRC projections have not taken into account the local variations in vertical land motion that occur. However, in guidance developed for the OPC, a three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City. The OPC-SAT subcommittee stated, “We do not believe that there is enough certainty in the sea-level rise projections nor is there a strong scientific rationale for specifying specific sea-level rise values at individual locations along California’s coastline.” (OPC, 2013, pg. 10)

Site-specific modifications to the NRC projections will be needed for the Humboldt Bay and Eel River estuary area, where the tide gauge records show a very different sea-level rise trend than what is projected for the North of Cape Mendocino region. The OPC-SAT Subcommittee advises that for the northern California coast, sea-level rise projections be developed from the recorded tide gauge rates at Humboldt and Crescent City “augmented by any future acceleration in rates of sea-level rise … for the areas closest to these gages, with intermediate values for the areas between them” (OPC 2013 pg. 11). Table 9 shows the historic sea level trend, based on tide gauge records for the North Spit of Humboldt Bay and for Crescent City that can be used for local sea-level rise adjustments for the area north of Cape Mendocino.

Table 9. Sea Level Trends for Humboldt Bay, CA and Crescent City, CA

Location	Period of Record	Sea Level Trend (ft/century)	Sea Level Trend (mm/yr)
Humboldt Bay	1977 - 2013	1.36 +/- 0.38	+4.14 +/- 1.15
Crescent City	1933 - 2013	-0.27 +/- 0.11	-0.81 +/- 0.33

Source: NOAA Tides and Currents, 2013, “Updated Mean Sea Level Trends”. Retrieved July 2, 2013 from http://tidesandcurrents.noaa.gov/sltrends/sltrends_states.shtml?region=ca.

The OPC-SAT Subcommittee recommended using the NRC sea-level rise projections for most locations south of Cape Mendocino, without local adjustments for vertical land motion. This recommendation should be given serious consideration. If a local government or project applicant should decide to include local vertical land motion, for a particular reason, the local land changes should replace the regional projections of vertical land change assumed by the NRC report (from Table 5.3 of the NRC Report and reproduced in Table 10). If local trends are applied to the regional projections, the inclusion of local uplift or subsidence will compound the regional land changes already included in the NRC Report.

Table 10. Regional Vertical Land Motions used in NRC Regional Sea Level Projections

	North of Cape Mendocino				South of Cape Mendocino			
	Centimeters		Inches		Centimeters		Inches	
	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
2000 – 2030	-3.0	-7.5 - +1.5	-1.1	-3.0 - + 0.6	4.5	0.6 – 8.4	1.8	0.2 – 3.3
2000 – 2050	-5.0	-12.5 - + 2.5	-2.0	-4.9 - +1.0	7.5	1.0 – 14.0	3.0	0.4 – 5.5
2000 – 2100	-10.0	25.0 - + 5.0	-4.0	-9.8 - +2.0	15.0	2.0 – 28.0	5.9	0.8 – 11.0

NOTE: Negative values show uplift and positive values show subsidence. If no sign is used, values are positive for subsidence.)

The NRC report provides some vertical land motion information to assist with modifying regional sea-level rise for local conditions. Appendix A of the NRC Report provides vertical land motions for eight California locations (Crescent City, San Francisco, Alameda, Port San Luis, Santa Monica, Los Angeles, La Jolla and San Diego). In addition, Appendix D of the NRC Report, "Long-term Tide Gage Stability from Land Leveling" provides a discussion on tide gauge observations, with long-term vertical land motion for Crescent City, San Francisco, Port San Luis, Los Angeles, and San Diego.

Local vertical land motion can be influenced by many of the factors. Each factor may alter vertical land motion differently and detailed projections of future vertical land motion may need to be developed from the trends for each of the individual components. Seismic activity can often influence vertical land motion and vertical land motion trends during times of high seismic activity may be very different from those recorded during periods of low seismic activity. Groundwater pumping and fluid extraction can have a major influence on vertical land motions. But, effects from fluid extraction will be localized and vertical land motion measurements close to the extraction areas will be needed to quantify local vertical land motion. Historic trends in vertical land motion for one location may not be appropriate for another location, even one that is only 5 or 10 miles away. Several programs have been established to better understand vertical land motion, but they have been in operation for at most a few decades, and long-term projections of vertical land motion are difficult to develop. Projections of local land motion introduce another layer of uncertainty into sea-level rise projections. When local vertical land motions are used to modify the regional sea-level rise projections, there should be at least one scenario that examines the consequences from the unmodified regional sea-level rise range.

Outcome of Step 3: *Step 3 provides a locally modified sea-level rise projection that can be used for project analysis or development of a plan.*

Step 4 – Project Tidal Range and Future Inundation

One of the most basic examinations of changing sea level conditions has been to determine the new intersection of mean sea level or other tidal levels with the shoreline. This has been called the "bathtub" analysis since it looks only at the expansion of areas that will be inundated (i.e. regularly submerged under water). The inundation level will move up in elevation and the zone of inundation will move inland, generally following the existing slope of the beach or shore. So the future inundation level can be approximated as the sum of the current water level plus future regional mean sea-level rise. The future inundation zone will be where this water level meets land.

Future Water Elevation = Current Water Elevation + Projected Sea-level rise

Future Water Location = Intersection of Elevation with Future Shore Location

For example, future sub-tidal levels would be the current subtidal limit plus projected regional mean sea-level rise. Future intertidal zones would be bounded by the current higher high tide level plus projected regional mean sea-level rise and lower low tide levels plus projected regional mean sea-level rise.[39] For some projects, such as wetland restoration, the identification of future inundation zones may be the only sea level analysis needed for project evaluation. If the shoreline is eroding, the location of this elevation would need to also incorporate the rate of erosion. So, not only will the intertidal zone move up in elevation, if the shoreline is expected to erode due to increased wave attack, the intertidal zone will be both higher than and inland of the current zone.

Inundation will extend to the location of the new inundation elevation. On beaches with a gradual slope, this can move the inundation location significantly inland, based on the slope (geometric conditions) of the beach. (This type analysis is often called the Bruun Rule). On a stable beach with a slope of 1:X (Vertical:Horizontal), every foot of vertical sea-level rise will move the inundation area horizontally X feet inland. For a typical 1:60 beach, every foot of sea level would move the inundation zone inland by 60 feet. If the beach is eroding, the loss due to inundation will add to the loss from erosion.

Figure 11 shows the influence of tides and sea-level rise on low-wave energy beaches. Table 11 provides some useful resources for inundation studies. For the open ocean coast, where waves are a dominant feature of a beach, the changes to the beach need to include waves, as discussed later in this section.

[39] Historic trends of high and low tide have changed differently than mean sea level (Flick et al. 2009). Based on historic trends, the changes to various tidal elements are likely to track closely with, but not identically with, changes to mean sea level. The future variability of changes to the tidal components, compared with changes to mean sea level will normally be within the uncertainty for sea-level rise projections and can be ignored for almost all situations. As this phenomenon of tidal change is better understood and can be modeled, it may be appropriate in the future to include the changes in tidal components into the analysis of inundation and various water level projections.

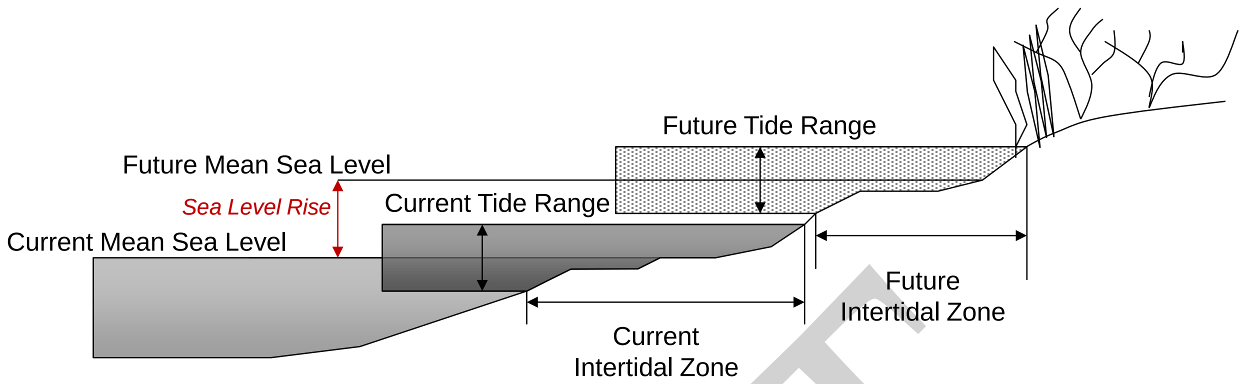

Figure 11. Sea-level rise and Changes to Tide Range and Intertidal Zone.

Table 11. General Resources for Inundation Studies

Resource	Specifics of Information	Source
Aerial Photographs	Useful for general information on shoreline trends Ortho-rectified photos can help quantify trends	California Coastal Records Project; www.californiacoastline.org Huntington Library Local Libraries
LIDAR	Fairly detailed topography Can provide GIS layers for current conditions Comparable with LIDAR data sets for temporal changes	NOAA Coastal Services Center - http://www.csc.noaa.gov/data/index.html
Topographic Maps	Often not at a scale to distinguish small changes in water levels	USGS Map Center - http://www.usgs.gov/pubprod/maps.html
NOAA Sea Level Rise Viewer	Useful to show changes in water level location if there are no changes in the land due to erosion.	NOAA's Digital Coast http://www.csc.noaa.gov/digitalcoast/tools/slrviewer
Tidal Data	Measured and predicted tidal components for locations along the open coast and in bays.	http://tidesandcurrents.noaa.gov/
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 1.4 meter rise in sea level and a 100-year flood event. Maps do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/

Outcome from Step 4: *Step 4 provides information on the projected changes to the tidal range and future zones of inundation. For locations without any influence from erosion, storm surge, or wave energy, the identification of new inundation areas may be sufficient for project analysis and planning efforts. This projected new inundation area may also be useful for anticipating the likely migration of wetlands and low-energy water areas or as input for analysis of changes groundwater salinity. For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 5 – Determine Water Level Changes from Surge, El Niños, PDO, etc.

Estimates of surge, El Niño and PDO water elevation changes are developed primarily from historic records. There are no state-wide resources for this information, although it may be included in one of the regional Coastal California Storm and Tide, Wave Studies prepared by the US Army Corps of Engineers. General guidance on water level changes that can be expected from surge and El Niños is provided in Table 12.

The remaining discussion provides general information on some of these phenomena. It is provided to acquaint readers to the main issues associated with each. Readers with a strong background in ocean-atmospheric conditions may want to skim or skip the rest of this section.

The Pacific Ocean is a complex system. Sea level in the Pacific Ocean is a response to multiple oceanic and atmospheric forcing phenomena, occurring with different intensities and at different temporal and spatial scales. Some phenomena may reinforce each other, while other may act in opposition, essentially canceling each other out. Scientists and researchers are attempting to identify the various signals from the multiple phenomena, but these are nascent sciences and there is still much we need to learn.

Regional water levels can be modified by surge as well as by high and low pressure systems. Surge is a short-term change in water elevation due to high wind, low atmospheric pressure, or both. It is most often associated with east coast and gulf coast hurricanes that can cause up to 15 or 20 feet (4 to 6 meters) or more of short-term water level rise over many miles of the coast. Along the west coast, storm surge is much smaller, and is rarely a coastal hazard, except in enclosed bays. In southern California it rarely exceeds one foot (0.3 meters) and in central California, it rarely exceeds 2 feet (0.6 meters). Surge becomes a concern because it is one of several cumulative factors that cause a temporary rise in sea level. Each rise may be small, but when they occur in combination or during high tides and with storms, they increase the threat of coastal flooding, wave impacts and erosion.

Two of the more recognized phenomena that affect water temperature in the Pacific are the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). ENSO cycles, which occur on inter-annual timescales (approximately 2-7 yr), involve ocean-basin-spanning changes in sea surface temperature (SST) and the depth of the mixed layer in the Equatorial Pacific, but also drive changes in ocean conditions and atmospheric circulation at higher latitudes. El Niño events result in the transfer of warm surface waters into the normally cool eastern equatorial Pacific, resulting in elevated SST and water levels along much of the west coast of the Americas. El Niños also tend to increase the strength and frequency of winter low pressure systems in the North Pacific. These events can persist for months or years at a time, and strongly influence local and regional sea level. For example, the pulse of warm water from the large 1982-83 El Niño caused water levels along the California to be elevated by approximately 0.4 - 0.7 feet (0.12 – 0.21 m) for many months, with short-term water elevation peaks up to about 1 foot (0.3 m) (Flick, 1998). The opposite phase of ENSO, characterized by unusually cool SSTs and lower water elevations along the eastern Pacific margin, are called La Niña events. Between El Niños and La Niñas are periods of neutral SST and water elevation changes.

The PDO is an ENSO-like pattern of SST and atmospheric variability occurring over multiple decades. In contrast to ENSO, the PDO is more strongly expressed in the North Pacific than in the tropics. The positive or warm phase of the PDO is associated with unusually warm surface water along eastern North Pacific (the western US coast), while the negative or cool phase PDO is associated with colder than normal water. As with the ENSO effects, the warm phase PDO has tended to cause elevated sea levels in the eastern Pacific and along the California coast, while the cool phase of the PDO tends to lower sea level in this region.

The PDO has basin-wide influence. Elevated water levels in one part of the Pacific are often accompanied by lowered water levels elsewhere. The cool phase PDO can result in a drop of water level along the eastern Pacific (western US coast) and a rise in water level along the western Pacific. Recently, sea level along the western Pacific has been rising about three times faster than the global mean sea-level rise rate (Bromirski et al., 2011; Merrifield, 2011). This does not mean the eastern Pacific will experience sea-level rise that is three times faster than the global mean sea-level rise when there is the next shift in the PDO, but does show that the PDO can have a major influence on basin-wide and regional sea level.

The above discussion of El Niño and the PDO suggests that there are well-understood, readily predicted changes in sea level that result from these phenomena. However, it is important to note that El Niños have varying strengths and intensities, resulting in different sea changes from one event to the next. And, changes in regional mean sea level along the eastern Pacific have not always shown a strong connection to the PDO cycles. An apparent jump in regional mean sea level occurred after the mid-1970s shift to the warm phase of the PDO, yet the expected continued rise in sea level along the West Coast seems to have been suppressed by other forces. Tide gauge records for the Washington, Oregon and California coasts have shown no significant interannual rise in sea level from 1983 to 2011 (Cayan et al., 2008; NOAA Tides and Currents, 2013; Bromirski et al., 2011). Bromirski et al. (2011 & 2012) postulate that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors cause a drop in sea level that may have cancelled out the sea rise that otherwise would be expected from a warm phase PDO signal.

Water level changes from surge, atmospheric forcing, El Niños and the PDO can occur in combination. The water elevations changes from each factor may each be only about a foot or less (less than 0.3 meters), but they can cause changes in the water level over a time period of days, months, or a few years -- far more rapidly than sea-level rise. In combination, they can cause a significant localized increase in water level.

When high water conditions occur in combination with high tides, and with coastal storms, the threat of coastal flooding, wave impacts and erosion also increases. These conditions can be additive, as shown in Figure 12. Also, these changes in water level will continue to be important to the overall water level conditions along the California coast and they need to be examined in conjunction with possible changes due to regional sea-level rise.

As stated earlier, estimates of surge, El Niño and PDO water elevation changes are developed primarily from historic records. There are no state-wide resources for this information, although it may be included in one of the regional Coastal California Storm and Tide, Wave Studies prepared by the US Army Corps of Engineers. General guidance on water level changes that can be expected from surge and El Niños is also provided in Table 12.

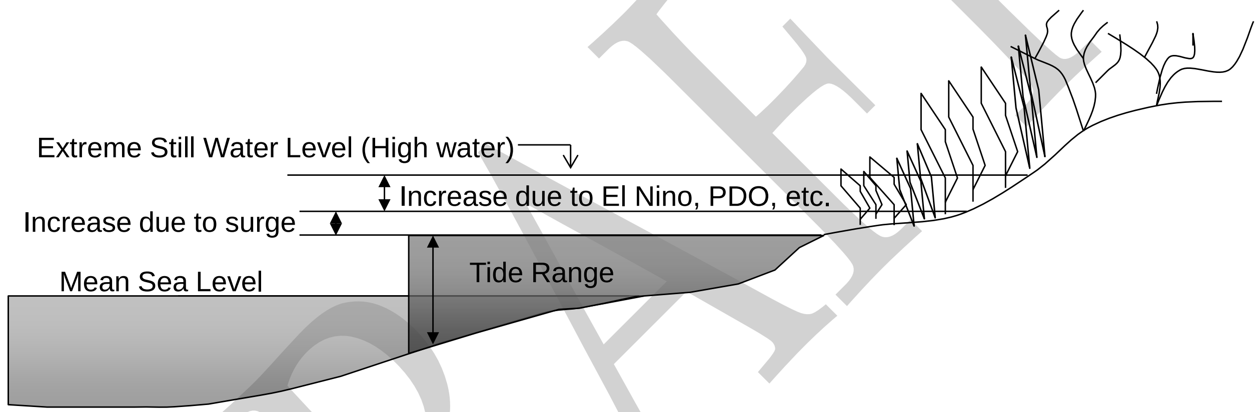

Figure 12. Changes to Extreme Still Water Level due to Surge, El Niños, PDOs, and such (Figure by L. Ewing, 2013).

Table 12. General Resources for Determining Still Water Elevation due to Surge, El Niños, PDOs.

Resource	Specifics of Information	Source
Sea-Level Rise Affecting Marshes Model (SLAMM)	Simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea-level rise. Map distributions of wetlands are predicted under conditions of accelerated sea-level rise, and results are summarized in tabular and graphical form.	http://www.warrenpinnacle.com/prof/SLAMM
NOAA Digital Coast Sea-Level Rise Viewer	Displays potential future sea levels within wetland areas, and provided visualizations for various amounts of sea-level rise. For bays and estuaries, it also provides information on inland areas with the potential to flood if existing barriers to water connectivity are removed or overtopped. Communicates spatial uncertainty of mapped sea-level rise, overlays social and economic data onto sea-level rise maps, and models potential marsh migration due to sea-level rise. Maps do not include any influence of beach or dune erosion.	http://www.csc.noaa.gov/digitalcoast/tools/slrviewer
Pacific Institute Sea-Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlayed on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea-level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report "The Impacts of Sea-Level Rise on the California Coast" visit: http://www.pacinst.org/reports/sea_level_rise/report.pdf
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 1.4 meter rise in sea level and a 100-year flood event. Maps do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/

Outcomes from Step 5*: Step 5 provides estimates of water elevations that can result from surge, El Niños and PDOs. When combined with the sea level changes to the tidal range, developed in Step 4, this can provide information on the extreme still water level. For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 6 – Estimate Beach, Bluff and Dune Change from Erosion

Predictions of future beach, bluff, and dune erosion are complicated by the uncertainty associated with future waves, storms and sediment supply. As a result, there is no accepted method for predicting future beach erosion. At a minimum, projects should assume that there will be inundation of dry beach and that the beach will continue to experience seasonal and inter-annual changes comparable to historic amounts. When there is a range of erosion rates from historic trends, the high rate should be used to project future erosion with rising sea level conditions. For beaches that have had a relatively stable long-term width, it would be prudent to also consider the potential for greater variability or even erosion as a future condition. For recent studies that provide some general guidance for including sea-level rise in an evaluation of bluff and dune erosion, see, for example, Heberger et al. (2009) or Revell (2011). Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used. Table 13, at the end of this section, provides some resources that can be used for projecting future erosion.

The following sections discuss specific concerns associated with beach, bluff and dune erosion and are provided to acquaint readers to the main issues associated with each system. Readers with a strong background in coastal systems may want to skim or skip the rest of this section.

Beach Erosion

Beach erosion and accretion occur on an on-going basis due to regular variability in waves, currents and sand supply. The movement of sand on and off of beaches is an ongoing process. Along the California coast, periods of gradual, on-going beach change will be punctuated by rapid and dramatic changes, often during times of large waves, or high streamflow events.

The overall dynamics of beach change have been described many times[40]. Sand moves both on and off shore as well as along the shore. Normal sources of sand to a beach are from rivers and streams, bluff erosion or gullies, and from offshore sand sources. Sand leaves a beach by being carried downcoast by waves and currents, either into submarine canyons or to locations too far offshore for waves to move it back onto shore. Beaches are part of the larger-scale sediment dynamics of the littoral cell, and in very simple terms beaches accrete if more sand comes onto the beach than leaves and beaches erode if more sand leaves than is added. Changes in sand supply are a major aspect of beach change.

[40] See for example, Bascom, 1980; Komar, 1998; Griggs et al., 2005.

Beach changes are often classified as being either seasonal or long-term/inter-annual changes. Seasonal changes are the shifts in beach width that tend to occur throughout the year and are usually reversible. Beaches tend to widen during the late spring and summer as gentle waves carry offshore sand up, onto the beach. Then during late fall and winter, beaches tend to become narrower as more high energy waves carry sand away from the beach and deposit in offshore bars. This is followed by beach widening as gentler waves again bring sand landward, building up a wider dry-sand summer beach. These changes are considered seasonal changes, and if the beach widths return to the same seasonal width each year, then the beach experiences seasonal changes but no long-term or inter-annual changes. If the seasonal beach widths become progressively narrower, these changes become long-term or inter-annual change and suggest a long-term beach change trend – accretion if the beach is widening and erosion if the beach is narrowing.

If development is at or near beach level, erosion of the beach can expose the development to damage from wave forces, flooding, and foundation scour. And waves that hit the coast bring with them vegetation, floating debris, sand, cobbles, and other material. This material can act like projectiles, adding to the flood damage and forces from the waves.

At present, about 66% of the California beaches have experienced erosion over the last few decades, with the main concentration of eroding beaches occurring in southern California (Hapke et al., 2006). This erosion has been due to a combination of diminished sand supplies and increased removal of sand by waves and currents. With rising sea level, beach erosion is likely to increase, due to both increased wave energy[41] that can carry sand offshore or away from the beach, and to decreased supply of new sediments to the coast[42].

There are several elements that will contribute to the effects of sea-level rise on seasonal and inter-annual beach change. There will be the changes to the beach due to inundation by rising water levels, as shown in Figure 13. (See discussion on inundation for more information on how to determine this change.) If the beach cannot migrate inland to accommodate these changes, then the inundation will result in a direct loss or erosion of beach width. This will result in a narrower seasonal beach as well as inter-annual loss of beach.

Seasonal and inter-annual beach conditions will also be affected by changes to waves and sediment supply. Since waves are sensitive to bottom bathymetry, changes in sea level may change the diffraction and refraction of waves as they approach the coast, and change the resulting mixture of beach-accreting and beach-eroding waves. However, the influence of climate change (not just rising sea level) on wave conditions, through changes in wave height, wave direction, storm frequency and storm intensity will likely be far more significant than the slight changes from bathymetric changes. In addition, changing precipitation patterns will modify the amount and timing of sediment delivery to the beach.

[41] In shallow water, wave energy is proportional to the square of the water depth. As water depths increase with sea-level rise, wave energy at the same location will likewise increase.
[42] Many parts of the developed coast are already experiencing drops in sand supplies due to upstream impoundments of water and sediment, more impervious surfaces, and sand mining.

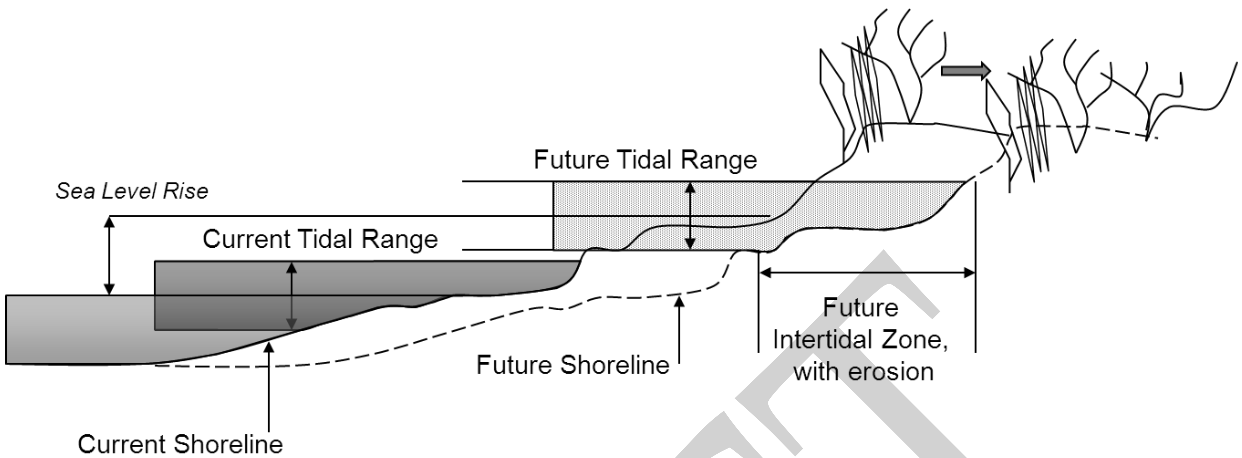

Figure 13. Changes to the Intertidal Zone with Sea-level rise and Erosion, without Wave Impacts (Figure by L. Ewing, 2013).

<u>Bluff Erosion</u>

A second type of erosion occurs on coastal bluffs[43]. There is no fully-accepted methodology for estimating future bluff erosion with sea-level rise. Guidance for coastal analysts in Hawaii is to assume erosion will increase as a proportion of historic erosion. (Hwang, 2005) One approach used in the past by the Commission has been to use the high range of historic erosion rates to represent average future trends. A more process-based methodology, used in the Pacific Institute study of erosion due to rising sea level, is to correlate future erosion rates of bluffs with increased frequency of wave impacts (Heberger et al., 2009; Revell, 2011). This approach assumes that all bluff erosion is due to wave impacts and erosion rates will change over time as the beach or bluff experiences more frequent or more intense wave attack. Such an approach should be considered for examining bluff erosion with rising sea level. Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used.

Bluff retreat occurs due to many different mechanisms. Landslides, slumps, block failures, gullies, and rilling are examples of bluff retreat. At the most basic level, bluff retreat or collapse occurs when the forces leading to collapse of the bluff face are stronger than the forces holding the bluff in place. Forces causing bluff retreat can include earthquakes, wind, burrowing animals, gravity, rain, surface runoff, groundwater, and sheet flow. Coastal bluffs have the added factor of wave attack, a factor that is not present for inland bluffs. Resistance to collapse is mainly a characteristic of the bluff material. For example, granitic bluffs like those along the Big Sur coast retreat at a much slower rate than the soft sandstone and marine terrace bluffs of Pacifica.

[43] Bluffs can be built or expanded during interglacial cycles or following seismic uplift. Many of the marine terraces that are visible along the California coast are remnants of past beach areas that have been uplifted to become bluffs and cliffs. However, natural bluff rebuilding is a millennial or multi-millennial process, and it will not occur during the time periods over which most development projects are evaluated.

Coastal bluff erosion can occur throughout the year, but it often occurs during or after storm periods, when the dry beach will be narrow or non-existent. When coastal bluffs are fronted by wide sand beaches, most waves break on the beach face and the beaches protect the bluffs from direct wave attack. When the beach is narrow, there is less buffering of the wave energy and waves can break directly against the bluffs. A general depiction of bluff retreat with rising sea level is provided in Figure 14.

Bluff retreat is often episodic – the bluff may be stable for a number of years and then retreat by tens of feet in a few hours or a few days. If the changes to a bluff are examined through endpoint analysis – i.e. looking first at the initial position of the bluff and then at the position of the bluff sometime in the future, researchers can determine the amount of retreat that has occurred during the time from the initial to final positions. This gives information on an average retreat rate that has occurred, but gives no information about the conditions leading to the retreat, or the progression of retreat and no retreat. The average retreat rates can give some indication of likely future changes, but they provide little information about when the next retreat episode might occur or how large it might be.

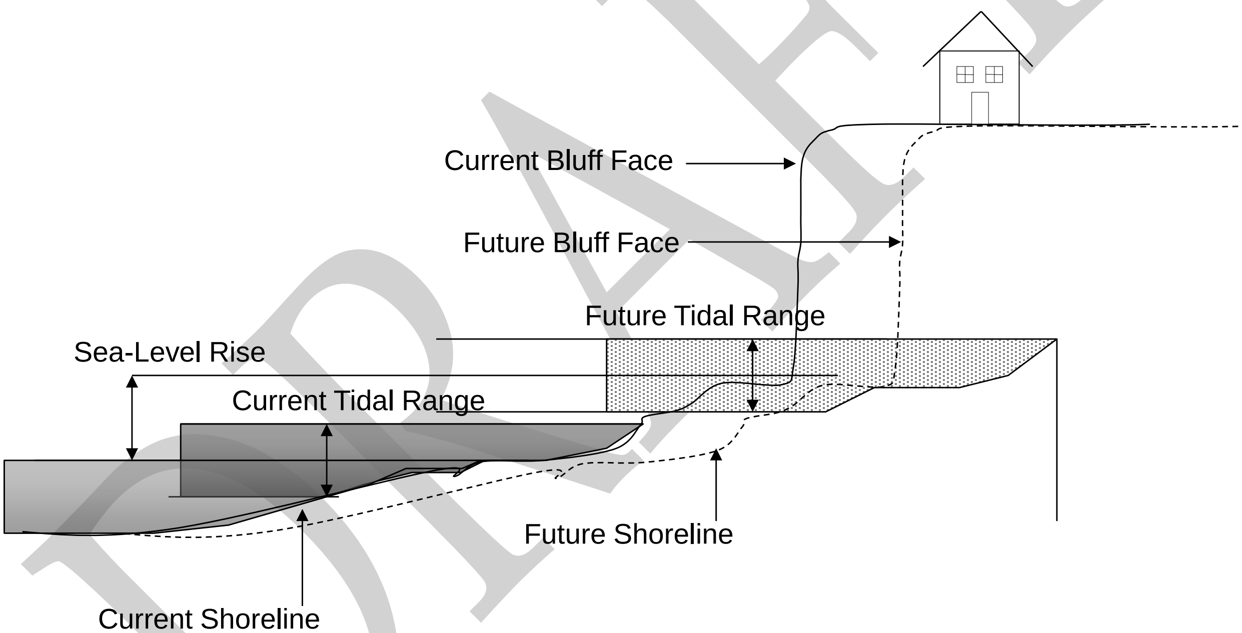

Figure 14. Bluff Erosion with changes in sea level (Figure by L. Ewing, 2013).

Dune Erosion

Just as there is no fully accepted methodology for estimating changes to beach or bluff erosion with sea-level rise, there is no fully-accepted methodology for dune erosion. A methodology somewhat similar to that for bluff erosion has been developed for dunes (Heberger et al., 2009; Revell, 2011), and such an approach should be considered for examining dune erosion with rising sea-level. Other approaches that recognize the influence of water levels in beach, bluff or dune erosion can also be used.

Dune erosion occurs when the waves break at or near the dunes, pulling sediment out of the dune. This process does deposit sand onto the beach or in the nearshore area, but can result in short term dune retreat. If sand is not returned to the dunes following these periods of short-term retreat, the sand losses will contribute to long-term dune erosion. When development is on the coastal dune, building damage occurs when the dune retreats back to the location of development, either through reversible, short-term retreat or long-term erosion. As with bluff erosion, the Pacific Institute work (Heberger et al., 2009) examined sea level related changes in dune erosion rates and has provided a methodology that can be considered in examining future changes to dune erosion with increased sea-level rise.

For individual cases, determinations of future retreat risk are based on the site-specific conditions, and professional analysis and judgment. However, the lack of information about the contributions of all the erosive forces to dunes and the beach-dune interactions makes it challenging to anticipate future changes to coastal dune retreat due to rising sea level and increased wave forces. As with beaches and bluffs for most situations, these historic conditions provide a lower limit for future dune retreat, or the upper limit of advance for those sites that are now experiencing accretion or quasi-stability. Projections of future erosion should either (1) use the high range of historic erosion, (2) develop a sea-level rise influenced erosion rate, as done by Heberger et al., 2009 or Revell, 2011, or (3) develop another approach that considers shoreline changes that are likely to occur under rising sea level conditions.

Table 13. General resources for information on beach, bluff and dune erosion

Resource	Specifics of Information	Source
Aerial Photographs	Useful for general information on shoreline trends Ortho-rectified photos can help quantify trends	California Coastal Records Project - www.californiacoastline.org; Huntington Library; Local Libraries
LIDAR	Fairly detailed topography Can provide GIS layers for current conditions Comparable with LIDAR data sets for temporal changes	NOAA Coastal Services Center - http://www.csc.noaa.gov/data/index.html
USGS National Assessment of Shoreline Change with GIS Compilation of Vector Shorelines	Statewide inter-annual beach and bluff erosion. GIS shorelines available for sandy shorelines & cliff edge. Shorelines show historic changes. Long-term (70 to 100 years); short-term (25 to 50 years. No projections of future erosion rates.	Sandy Shorelines -- Open File Report 2006-1219; GIS Data in Open File 2006-1251 http://pubs.usgs.gov/of/2006/1219 and http://pubs.usgs.gov/of/2006/1251 Bluff Shorelines – Open File Report 2007-1133; GIS Data in Open File 2007-1251 http://pubs.usgs.gov/of/2007/1133 and http://pubs.usgs.gov/of/2007/1112
Regional Sediment Management Studies	Summaries of seasonal and long-term erosion studies	CSMW Website; http://dbw.ca.gov/csmw/default.aspx

Corps of Engineers, Coast of California Studies	Summaries of seasonal and long-term erosion studies	Studies for many regions are available through an internet search. Addresses are too numerous to list here.
Beach Profiles and Surveys	Detailed Beach or Bluff changes with time	NOAA, Coastal Services Center - http://www.csc.noaa.gov/data/index.html; US Army Corps of Engineers; Regional Beach Studies; University Studies
The Impacts of Sea-level rise on the California Coast (Pacific Institute Report)	Show expected changes to bluff position over time for sea-level rise of 1.4 meters from 2000 to 2100 for California coast from Oregon border through Santa Barbara County.	Pacific Institute Web site - http://www.pacinst.org/reports/sea_level_rise/maps/
CoSMoS	COSMOS is a tool for predicting climate change impacts from storms. It does not predict long-term erosion, but can provide general information for short-term, storm-drive beach changes. Only available, at present, for the central coast.	http://data.prbo.org/apps/ocof/

Outcome from Step 6: *Step 6 provides projections of future long-term beach, bluff or dune erosion that takes into account sea-level rise. For locations without any influence from storm surge, or wave energy, the identification of the extent of beach, bluff or dune erosion may be sufficient for project analysis and planning efforts. This projected new erosion area may also be useful for anticipating the appropriate setback distance for otherwise stable land forms (If slope stability if a concern, refer to Commission guidance on setbacks (Johnsson 2005. Available: http://www.coastal.ca.gov/W-11.5-2mm3.pdf)). For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 7 – Determine Wave, Storm Wave, Wave Runup and Flooding Conditions

The main concerns with waves, storm waves, and runup are flooding and wave impacts. Flooding is the temporary wetting of an area by waves, wave runup, surge, atmospheric forcing (such as water elevation during El Niño events) and, at river mouths, the combination of waves and river flows. Wave impacts occur when high-energy waves, often associated with storms, reach backshore areas or development. Coastal flooding and wave impacts are worst when they coincide with high water level events (high tide plus high inundation). As sea level rises, inundation will move inland, and so will flooding and wave impacts. Beach erosion will aggravate these conditions and add to the inland extent of impacts.

Flooding: In most situations, factors that result in high water conditions, such as tides, surge, El Niños, and PDOs, should be used to determine flood conditions and flood areas, as shown below. If the area is exposed to storm waves, these forces should be examined as well.

Future Flooding = Future Higher High Tide + Surge + Forcing + Wave Runup

Flooding Areas = Flooding + seasonal eroded beach + long-term beach erosion

Waves: Wave impacts depend greatly upon storm activity – both the intensity and the duration of the storm. Normally projects have used design wave conditions comparable to the 100-year event. For critical infrastructure or development with a long anticipated life expectancy it may be advisable to use a greater design standard, such as a 200-year or 500-year event. So, some proposed projects may want to adjust design waves or frequency of high energy waves to analyze the consequences of worsening wave impacts.

Wave impacts to the coast, to coastal bluff erosion, and to inland development should be analyzed under the conditions most likely to cause harm. Those conditions normally occur in winter when most of the sand has moved offshore, leaving only a reduced dry sand beach to dissipate wave energy. Since the development will be in place for a number of years, on beaches that will experience long-term erosion, the beach changes expected to occur over the life of the development should also be considered. Just as the beach conditions should be those least likely to protect from damage over the life of the development, so too should the water level conditions be those most likely to contribute to damage over the life of the development. Waves that cause significant damage during high tide will be less damaging during low tide; all other things being equal, waves will cause more inland flooding and impact damage when water levels are higher. Since water levels will increase over the life of the development due to rising sea level, the development should be examined for the amount of sea-level rise (or a scenario of sea-level rise conditions) that is likely to occur throughout the expected life of the development. Then, the wave impact analysis will examine the consequences of a 100-year design storm event, with water levels likely to occur due to high water conditions and sea-level rise, and with a long-term and seasonally eroded beach.

Eroded Beach Conditions = seasonal erosion + long-term erosion*

High Water Conditions = High tide + relative sea-level rise* + atmospheric forcing

Wave Conditions = 100-year Design Storm + High Water + Eroded Beach

* The time period for both long-term erosion and relative sea-level rise will be at least as long as the expected life of the development.

The remaining discussion provides general information about waves, the California wave climate and coastal flooding. It is provided to acquaint readers to the main issues associated with waves and coastal flooding. Readers with a strong background in waves or coastal processes may want to skim or skip the rest of this section.

Waves, like tides, cause constant changes to the water levels that are observed at the coast. The rhythmic lapping of waves on the beach during summer can be one of the joys of a beach visit. At other times of the year, waves can increase in size and energy and damage or destroy buildings, and cause erosion of bluffs and cliffs. Routine ocean waves are generated by wind blowing across the surface of the water. Once generated, waves can travel far from their source, combining with waves generated from other locations, resulting in the rather erratic and choppy water levels that are seen in most of the ocean. But, as waves move into shallow water and approach land, they take on a more uniform appearance, aligning somewhat parallel to the shoreline through processes of refraction and diffraction. During most of the year, moderate short-period waves break once they are in water depths of approximately 1.3 times the wave height.

Storm Waves: During storm conditions, winds can transfer large amounts of energy into waves, increasing the wave height, length and period. Energy transfer to waves depends upon three conditions, the wind energy that is available to be transferred to the water (intensity), the length of time over which the wind blows (duration), and the area over which the wind blows (the fetch). As any of these conditions increase, the energy in the waves will increase, as will the energy that these waves bring to the coastline. Coastal scientists separate waves that are generated far from the coast (swell) from waves that are locally generated (seas). Storms in the mid-Pacific can cause storm-like wave conditions along the coast, even when there are no storms in the area. Likewise, a local storm can cause storm waves along one part of the coast while waves in other sections of the coast may be fairly mild.

Some of the worst storm wave conditions occur when there are intense storms along a large portion of the coast, and when this large, distantly generated swell combines with local seas. This was the case during part of the 1982-83 El Niño storm season when waves from a distant storm combined with locally generated waves and made landfall during high tide. As a result, approximately 3,000 homes and 900 businesses were damaged, and 33 buildings were destroyed. Damages exceeded $100 million to structures and $35 million to public recreational infrastructure (in 1982 dollars) (Flick, 1998).

Wave Runup: Wave runup, as depicted in Figure 15, is the distance or extent that water from a breaking wall will extend up a beach or structure. Much of the wave energy will dissipate during breaking, but wave runup can also be damaging. The runup water moves quickly; it can scour or erode the beach, damage structures, and flood inland areas.

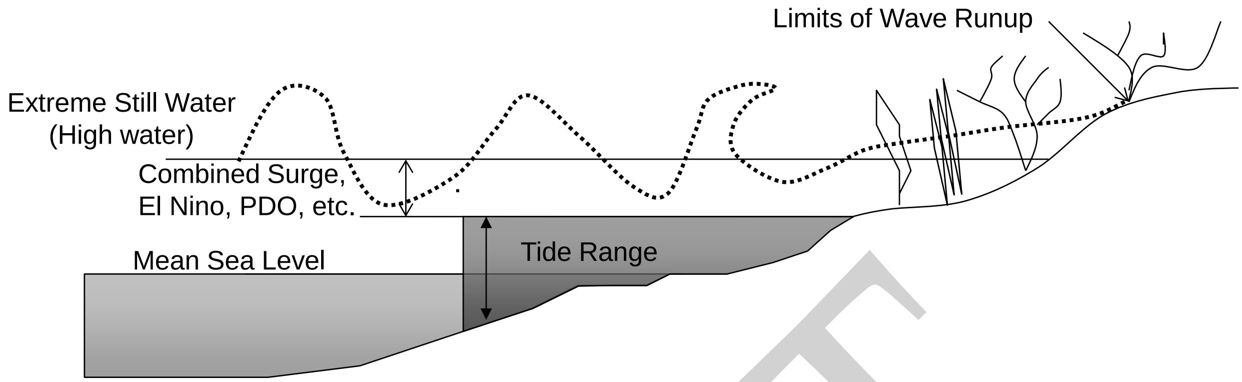

Figure 15. Wave Runup combined with Extreme Still Water (High Water) (Figure by L. Ewing, 2013).

Damage from waves and wave runup may increase in the future, due both to rising sea level and to changes in storm intensity and frequency. Waves will break farther landward when water levels are higher. Therefore, increased water levels due to tides, surge, ENSO or PDO variability, or sea-level rise will enable more wave energy to reach the beach, back shore, or inland development. The higher water levels do not change the waves. Rather, higher water levels change the point of impact, the extent of runup, and the frequency of wave impact. In locations where high waves now hit the coast, that frequency will increase. In locations where high waves rarely hit the coast, exposure to wave impacts will increase. Increased exposure to wave impacts or wave runup can cause a greater risk of flooding, erosion, and/or bluff failure.

Summary: Coastal flooding is a significant problem now and it will increase with rising sea level. At present, about 210,000 people in California are living in areas at risk from a 100-year flood event (Heberger et al., 2009). A rise in sea level of 55 inches (1.4 meters) and with no change in development patterns or growth along the coast, could put 418,000 to 480,000 people at risk from a 100-year flood (Cooley et al., 2012). Increases in storm intensity, or in the density of development in flood-prone areas, will increase the number of people at risk from flooding.

The frequency and intensity of high wave events depends upon the storm conditions that generate the waves. There is less consistency in the output of climate models related to projections of future storm conditions than there has been for temperature projections. A recent report on coastal flooding from 2000 to 2100 for the California coast has found that “storm activity is not projected to intensify or appreciably change the characteristics of winter nearshore wave activity of the twenty-first century.” (Bromirski et al., 2012, p. 33) This continuation of current storm conditions is not, however, an indication that storms will not be a problem in the future. Storm damage is expected to continue, and, if sea-level rise by the end of the twenty-first century is close to the high projections of about 55 inches (1.4 meters), “coastal managers can anticipate that coastal flooding events of much greater magnitude than those during the 1982-83 El Niño will occur annually.” (Bromirski et al., 2012, p. 36)

For most situations, the 100-year storm event will be used as the design storm. This is equivalent to a storm with a 1% annual probability of occurrence. However, most development does not stay for only a year and this probability of occurrence grows over time such that there is a 25% probability of occurrence during 25 year and over 55% probability that this storm will occur at least once during a 75 year period. Even so, the 100-year storm event, like the 100-year flood event, is often used as a design standard for development. However, for structures with a very long projected life or for which storm protection is very critical, a larger, 200-year or 500-year event might be appropriate.

Table 14 lists many of the resources that are available for finding regional or state-wide information on waves and flooding. Local communities often may have records of major erosion episodes or flood events.

Table 14. General Resources for Flooding and Wave Impacts

Resource	Specifics of Information	Source
CDIP (Coastal Data Information Program)	Current and historic information on wind, waves, and water temperature, wave and swell models and forecasting. As of 2013, there are 19 active stations along the California coast.	http://cdip.ucsd.edu/
Flood Insurance Rate Maps (FIRMs)	FEMA is updating coastal flood maps. Existing FIRMs are based on 1980s topography; flooding includes seasonal beach change but not long-term erosion. Maps do not include sea-level rise. Inclusion of a site shows a flood hazard; but exclusion does not necessarily show a lack of flood hazard.	FEMA Flood Map Center
Regional Sediment Management Studies	Some studies show elements of beach flooding and wave impacts	CSMW Website - http://dbw.ca.gov/csmw/default.aspx
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 1.4 meter rise in sea level and a 100-year flood event. Maps do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
FEMA Flood Hazard Mapping Guidance	Subsection D.2.8 provides guidance for calculating wave runup and overtopping on barriers. There are special cases for steep slopes and where runup exceeds the barrier or bluff crest.	http://www.fema.gov/library/file?type=publishedFile&file=frm_cfhamagd28.pdf&fileid=73be5370-c373-11db-a8db-000bdba87d5b
US Army Corps of Engineers, Coastal Engineering Manual	Detailed information on all aspects of deepwater wave transformation, shoaling, runup, and overtopping.	http://chl.erdc.usace.army.mil/cem

European Overtopping Manual	Descriptions of available methods for assessing overtopping and its consequences. Provides techniques to predict wave overtopping at seawalls, flood embankments, breakwaters and other shoreline structures facing waves. Supported by web-based programs for the calculation of overtopping discharge and design details	http://www.overtopping-manual.com/
CoSMoS	COSMOS is a tool for predicting climate change impacts from storms. It does not predict long-term erosion, but can provide general information for short-term, storm-drive beach changes. Only available, at present, for the central coast.	http://data.prbo.org/apps/ocof/
OCOF	(See CoSMoS)	http://data.prbo.org/apps/ocof/

Outcome from Step 7: *Step 7 provides projections of future flooding and wave impacts resulting from waves, storm waves and runup, that takes into account sea-level rise.*

Step 8 – Examine potential flooding from extreme events

Extreme events[44], by their very nature, are beyond the normal events that are considered in most shoreline studies. For an individual storm, that might be one with an intensity at or above the 100-year event. Or, extreme events could arise from a series of large, long-duration storms during high tides or from a local storm that coincides with the arrival of distant swell and high tides. Global sea-level rise greater than that projected to occur by 2100, when combined with a large storm during normal tides could develop into an extreme event. Rapid subsidence, as might happen along the northern CA coast during a Cascadia Subduction Zone earthquake, would be an extreme event. These are the outlier events that need to be anticipated and their consequences will need to be considered in planning and project analysis. In many situations, this consideration might be qualitative with consideration for the consequences that could happen if an extreme event does occur and opens up opportunities to address some of those consequences through design and adaptation.

In California, there may be some worsening of extreme precipitation and inland flooding from projected changes to atmospheric rivers. In general, however, future extremes are likely to be comparable to the extremes of today, but with the added influence of sea-level rise. Extreme

[44] In its report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, the IPCC defines extreme events as “a facet of climate variability under stable or changing climate conditions. They are defined as the occurrence of a value or weather or climate variable above (or below) a threshold value near the upper (or lower) ends (“tails”) of the range of observed values of the variable” (IPCC, 2012).

storm waves or floods can be addressed with the guidance provided earlier, except that the extreme storm conditions would be used. For tsunamis it is recommended that, for most situations, the appropriate projection of sea-level rise be added to the currently projected inundation level from tsunamis. This will provide a close approximation for future inundation from extreme tsunamis. If detailed analysis of future tsunami impacts is needed, someone experienced in modeling tsunami waves should be contacted.

Tsunamis: Tsunamis are large, long-period waves that can be generated by submarine landslides, large submarine earthquakes, meteors, or volcanic eruptions. They are rare events, but can be extremely destructive when they occur. There has been no research that suggests tsunamis could worsen in the future through some link with climate change. However the extent of tsunami damage will increase as rising water levels allow tsunami waves to extend farther inland. Thus the tsunami inundation zone will expand inland with rising sea level. There is no direct connection between tsunamis and either sea-level rise or climate change. But, for coastal areas that are at risk from tsunamis, the inundation zone will change as sea-level rises.

The detailed changes to the inundation zone with rising sea level would need to be determined by modeling. However, modeling of long-waves, such as tsunamis, is a specialized area of coastal engineering, and will not be covered in this general guidance. For most situations, it will be sufficient to get information on possible inundation from the most recent tsunami inundation maps (currently on the Department of Conservation website, http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx). As a rough approximation, the change to the inundation level can be estimated as equal to the change water elevation due to sea level. So, a one-foot rise in sea level could be assumed to result in a one-foot rise in the inundation elevation. However, in many places, particularly shallow bays, harbors, and estuaries, the change in tsunami inundation zone is likely to scale non-linearly with sea-level rise and require careful modeling. In areas with high tsunami hazards, or where critical resources are at risk, a site-specific analysis of sea-level rise impacts on tsunami hazards is crucial and someone experienced in modeling tsunami waves should be contacted.

Summary: Many different factors affect the actual water levels that occur along the coast and resulting hazards. In California, waves and tides have the largest routine effect on water levels. Tsunamis may have a very large, but infrequent effect of water levels. Sea-level rise will affect water levels all along the coast. Until the mid-century, the effects of tides and storms are expected to have the biggest effect on local water levels, with sea-level rise being a growing concern. For the second half of the century, sea-level rise is expected to become increasingly important for water levels and in damages to inland areas from flooding, erosion and wave impacts. Table 15 provides a general characterization of all the factors that can affect local water levels, with general estimate of their range and frequency of occurrence.

Table 15. Factors that Influence Local Water Level Conditions

Factors Affecting Water Level	**Typical Range for CA Coast (m)**	**Typical Range for CA Coast (feet)**	**Period of Influence**	**Frequency**
Tides	1 – 3	3 – 10	Hours	Twice daily
Low pressure	0.5	1.5	Days	Many times a year
Storm Surge	0.6 – 1.0	2 – 3	Days	Several times a year
Storm Waves	1 - 5	3 – 15	Hours	Several times a year
El Niños (within the ENSO cycle)	< 0.5	<1.5	Months - Years	2-7 years
Tsunami waves	6 – 8	20 – 26	Minutes to Hours	Infrequent but unpredictable
Historic Sea Level, over 100 years	0.2	0.7	On-going	Persistent
NRC State-wide Sea Level Projections 2000 – 2050	0.2 – 0.4	0.7 – 1.4	Ongoing	Persistent
NRC State-wide Sea Level Projections 2000 - 2100	0.1 – 1.43 m (North of Cape Mendocino) 0.42- 1.67 m (South of Cape Mendocino	0.3 – 4.69 ft (North of Cape Mendocino) 1.38 – 5.48 ft (South of Cape Mendocino)	Ongoing	Persistent

NOTE: All values are approximations. The conversions between feet and meters have been rounded to maintain the general ranges and they are not exact conversions.
Sources: Flick, 1998; NRC, 2012; Personal communications from Dr. Robert Guza (Scripps Institution of Oceanography) and Dr. William O'Reilly (Scripps Institution of Oceanography and University of California, Berkeley); and personal judgment of staff.

Outcome from Step 8: *Step 8 provides projections of potential flooding from extreme events including rapid subsidence, extreme precipitation, and tsunamis.*

APPENDIX C. ADAPTATION MEASURES

An adaptation measure is an action that minimizes risks from sea-level rise. Examples include changes in siting and design requirements, elevating the foundation of an individual structure, or moving a structure inland. Many adaptation measures benefit multiple coastal resources, and some adaptation measures fit into multiple categories, as shown the in tables below. Implied in each of these measures is the goal to protect and restore current and future coastal and marine resources and existing development, in accordance with the policies of the Coastal Act.

The Commission staff has compiled a list of potential adaptation measures for use in coastal development permitting and planning efforts and divided the measures into seven categories based on the requirements of the California Coastal Act. The adaptation measures in each category are listed in alphabetical order in the following tables.[45]

1. **Community Level Planning** – Table 16
2. **Site Development Standards and/or Mitigation –** Table 17
3. **Shoreline Protection and Management –** Table 18
4. **Natural Resources –** Table 19
5. **Water Quality and Water Supply Management –** Table 20
6. **Other Adaptation Measures –** Table 21

Description of Adaptation Measures

1. Community Level Planning Measures

Community level planning includes adaptation measures that are designed to guide development at a community, neighborhood, or hazard area scale. The measures generally apply to more than one parcel. Community level planning measures include:

- Concentration of development/Smart Growth
- Design standards
- Hazard zoning/ Overlay zones
- Land division requirements
- Transfer of Development Rights programs (TDR)
- Preserving open space
- Conservation easement programs
- Regional Sediment Management (RMS) programs

[45] The list of adaptation measures and descriptions were adapted and compiled various sources, including NOAA's "Adaptation to Climate Change: A Planning Guide for State Coastal Managers" (NOAA, 2010), Georgetown Climate Center's "Adaptation Tool Kit: Sea Level Rise and Coastal Land Use" (Grannis, 2011), EPA's Climate Ready Estuaries "Synthesis of Adaptation Options for Coastal Areas" (EPA, 2009), and Coastal Commission staff (personal communication, 2012-2013).

Table 16. Community Level Planning

Adaptation Measure	Description	Applicability to sea-level rise
Concentration of development/ Smart Growth	Require development to concentrate in areas that can accommodate it without significant adverse effects on coastal resources. This action should be consistent with Section 30250 and other policies of the Coastal Act.	Concentrate new development away from areas that are highly vulnerable to sea-level rise. This action is also applicable to CDPs for multiple lots.
Design standards	Establish and implement standards for building construction that minimize risks from flooding and erosion and increase resilience to extreme events.	LCPs should establish building standards to minimize hazards from sea-level rise. Standards may include higher base flood elevations, floating structures, and easily moveable structures, as well as strategies to reduce impacts from flood waters, such as green infrastructure and pervious surfaces.
Hazard zoning/ Overlay zones	Requires that new development is sited and designed to avoid highly hazardous or environmentally sensitive areas.	Update land use designations and zoning to identify areas that are vulnerable to sea-level rise impacts and to develop special regulations for those areas. Zoning regulations will need to be certified through an LCP Amendment.
Land division Requirements	Establish requirements for land divisions, lot creation, and lot line adjustments.	LCPs should limit subdivisions in hazard areas or require lots to meet specific standards in order to protect resources and prevent hazards. Also applicable to CDP.
Transfer of Development Rights programs (TDR)	Restrict development in one area (“sending area”) and allow for the transfer of development rights to another area more appropriate for intense use (“receiving area”).	LCPs can establish policies to implement a TDR program to restrict development in areas vulnerable to sea-level rise and allow for transfer of development rights to inland parcels with less vulnerability to hazards.
Preserving open space	Preserve land for its ecological or recreational value. Includes prohibiting development and any uses that conflict with ecological preservation goals.	LCPs can promote the preservation of open space, especially undeveloped areas vulnerable to sea-level rise impacts, through zoning restrictions or establishment of a defined urban/rural boundary.

Conservation easement program	Establish a formalized program to identify, acquire, and manage areas appropriate for some form of conservation protection. The program might develop standard agreements to be used for easements and chain of title, and identify the entities that could hold the easements.	LCPs can use a conservation easement program to limit or restrict development on portions of a lot parcel that would be most vulnerable to sea-level rise impacts. Parcel by parcel application would be accomplished through the CDP.
Regional Sediment Management (RSM) Program	Manage sediment to benefit a region, allow use of natural processes to solve engineering problems. To be most effective RSM will include the entire watershed, account for effects of human activities on sediment and protect and enhance coastal ecosystems.	LCPs can include support for development of an RSM program, and, once developed, supporting the management efforts identified by the RSM, and requiring that the plans be updated to include changes from sea-level rise. Natural boundaries for RSM may overlap with portions of several LCPs, so cooperation may be needed for best implementation. Individual actions would be accomplished through a CDP.

2. Site Development Standards and/or Mitigation

Site development standards are adaptation measures that are designed to reduce risks from sea-level rise at the individual parcel level. Mitigation measures are actions required as part of a coastal development permit to minimize hazards or adverse impacts to coastal resources. These include:

- Conditional permitting of shoreline protection structures
- Conservation easements
- Infrastructure-service protection
- Permit conditions
- Real estate disclosure
- Redevelopment restrictions
- Setbacks
- Siting and design

Table 17. Site Development Standards and/or Mitigation

Category	Description	Applicability to sea-level rise
Conditional permitting of shoreline protection structures	Add conditions to the shoreline protection permits, such as conditions that require the removal or modification of armoring in the future if need for protection or site conditions change.	Require shoreline protection to be removed, or considered for removal if the structure for which it was installed no longer exists or needs protection.
Conservation Easements	Provide a flexible mechanism by which a land trust or public entity can preserve land in its natural state while allowing land to remain in private ownership.	Where applicable, conservation easements can be required as a condition of a CDP. Also, LCPs can include policies to specify when such mitigation is appropriate or required.
Infrastructure-service protection	Establish measures that ensure continued function of critical infrastructure, or the basic facilities, services, networks, and systems needed for the functioning of a community.	LCPs can identify critical infrastructure vulnerable to hazards from sea-level rise, and can include criteria for managed relocation of at-risk facilities and direction to ensure continued function of critical infrastructure given sea-level rise and extreme storms. Can involve repair and maintenance, elevation or spot-protection of key components or fortification of structures where consistent with the Coastal Act.
Permit conditions	Conditionally approve a CDP to identify and require resource protective mitigation necessary to address impacts associated with locating development in an area subject to sea-level rise.	To mitigate impacts associated with locating new development in areas subject to sea-level rise, CDPs can include conditions that require: removal of structures if threatened, conservation easements, flood protection measures commensurate with rising sea level, and waiver of any rights to future shoreline protection.
Real estate disclosure	Require sellers of real estate to disclose certain property defects to prospective buyers prior to close. This action enables potential buyers to make informed decisions regarding the level of impacts they may experience.	Disclosures should include information about known current and potential vulnerabilities to sea-level rise.

Redevelopment restrictions	Limit the extent of redevelopment that can occur in hazardous areas without a Coastal Development Permit.	LCPs should clarify the definition of redevelopment so that in areas vulnerable to sea level hazards, redevelopment will not increase non-conformance and that eventually, uses will convert to conforming through permitted redevelopment.
Setbacks	Set building restrictions that limit the portions of a lot that can be used for development. When used for hazard concerns, they are normally defined by a measurable distance from an identifiable location such as a bluff edge, line of vegetation, dune crest, or roadway.	LCPs can establish the general guidance (including the time period over which the setback should be effective) and criteria for establishing setbacks from bluffs and dunes that take into consideration changes in retreat due to sea-level rise. CPDs should require detailed, site-specific analyses to determine the size of the setback to take into account sea-level rise.
Siting and design	Determine where development can be located in order for it to be safe from hazards over the economic life of the development.	Incorporate sea-level rise into existing hazard analyses as part of the siting and design process.

3. Shoreline Management and Shore Protection

Shoreline management is a term used to describe actions to proactively preserve or manage a shoreline area. Measures include programs to nourish beaches, restore sediment supply, or maintain dunes. Shore protection includes measures that serve to reduce or eliminate upland damage from wave action or flooding during storms, and include natural measures such as living shorelines or placement of sand and hardened options such as seawalls or riprap. The shoreline management and shore protective measures include:

- Beach nourishment and replenishment
- Dredging management
- Dune management
- Hard Protection
- Living Shorelines
- Maintenance or restoration of natural sand supply
- Removal of shoreline protection structures
- Sediment management
- Soft protection
- Waiver of right to future shoreline protection

Table 18. Shoreline Management and Shore Protection Measures

Category	Description	Applicability to sea-level rise
Beach nourishment and replenishment	Placement of sand on beaches to reduce erosion, enhance recreation, or preserve or enhance the aesthetic and habitat value of beaches. Sand sources may include offshore dredge sites ("borrow areas"), nearby harbor or channel dredging projects, wetland restoration projects or inland development. Generally has fewer environmental drawbacks than hard armoring, but can negatively affect species living, feeding, and nesting on the beach, especially during and immediately after sand placement. Most effective for areas with some existing beach.	LCPs can identify locations where beach nourishment may be appropriate, possibly through a Regional Sediment Management program. If beach nourishment is appropriate, the LCP should establish criteria for the design, construction and management of the nourishment area that includes likely changes in beach conditions due to sea-level rise into beach nourishment and replenishment plans.
Dredging management	Dredging involves the removal of sediment from harbor areas to facilitate boat and ship traffic or from wetland areas for restoration.	Dredging management actions and plans may need to be updated to account for elevated water levels. LCPs and CDPs should facilitate delivery of clean sediment extracted from dredging to nearby beaches where needed.
Dune management	Establish management actions to maintain and restore dunes. Dunes provide buffers against erosion and flooding by trapping windblown sand, storing excess beach sand, and protecting inland areas, and they also provide habitat. Most effective for areas with some existing dune habitat and where there is sufficient space to expand a foredune beach for sand exchange between the more active (beach) and stable (dune) parts of the ecosystem.	LCPs can identify existing dune systems and develop or encourage the development of management plans to enhance and restore these areas, including consideration of ways that the system will change with rising sea level. CDPs for dune management plans may need to include periodic reviews so the permitted plans can be updated to address increased erosion from sea-level rise, and the need for increased sand retention and replenishment.

Hard Protection	"Hard" coastal protection is a broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. Breakwaters, groins, and jetties may or may not be considered hard protection, depending upon their purpose and use with other "soft" protection.	LCPs can discourage the use of hard protection unless no other feasible alternative is available. LCPs should also develop design standards for the more frequently used hard protection and require designs that address or can be adapted to changing sea level. CDPs should require that hard protection be monitored for damage from sea-level rise hazards, that permits be re-opened after some time period to assess effectiveness in light of sea-level rise, and that removal options be incorporated into the design, in the event the structure may no longer be useful or appropriate in the future.
Living shorelines	Living shorelines are an approach to stabilize shoreline areas while maintaining valuable habitat and natural shoreline processes. These shorelines are designed with plants, sand, and limited amounts of rock to restore and enhance coastal habitats, promote sedimentation, and protect against shoreline erosion. They are effective in low-to-medium-energy coastal and estuarine areas and tidally influenced creeks, streams, and rivers.	LCPs can identify the local areas where living shorelines are most appropriate and develop guidance for implementation, monitoring, and evaluation. CDPs should require living shorelines where feasible and consistent with the Coastal Act. Require any living shorelines to take into account sea-level rise and storm events.
Maintenance or restoration of natural sand supply	Adjustment of the sediment supply has been one of the ways natural systems have accommodated changes from sea level. Maintenance or restoration of sediment involves identifying natural sediment supplies and removing and/or modifying existing structures or actions that impair natural sand supply, such as dams or sand mining.	LCPs should include policies and implementing standards that support nature-based responses to sea-level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to regulate sand mining, sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea-level rise.

Removal of shoreline protection structures	When shoreline protection structures are no longer needed or are in a state of great disrepair, their removal can open beach or wetland areas to natural processes and provide for natural responses to sea-level rise.	LCPs can specify priority areas where shoreline protection structures should be removed, including areas where structures threaten the survival of wetlands and other habitat, or beaches, trails, and other recreational areas. Through the LCP, removal might be accomplished by offering incentives for removal to property owners and by incorporating removal of public structures into Capital Improvement Plans. Conditions can also be added to CDPs that require removal of shoreline protection structures after certain thresholds are passed.
Soft protection	"Soft" coastal protection methods replenish, enhance, or mimic natural buffers, and they include beach nourishment, living shorelines, or wetlands. Often most effective where similar soft protection already occurs. Many soft protection methods may also be part of a green infrastructure program.	LCPs can promote the use of soft protection where feasible, through requirements that it be considered whenever shoreline protection is deemed necessary, and through the development of an RSM program that can promote soft solutions. CDP applications should require detailed evaluation of soft options in the alternatives analysis and require the use of soft protection where feasible and consistent with the Coastal Act. Sea-level rise and storms should be incorporated into the siting and design of any soft protection projects.
Waiver of right to shoreline protection	Property owners waive the right to future shoreline protective devices. The waiver specifies that no bluff or shoreline protective device is allowed to protect the development if it is threatened by natural hazards in the future. Instead, development will be removed or relocated if threatened by natural hazards.	As part of a CDP, require property owners to waive their right to future shoreline protection devices. The LCP can contain a policy stating that CDPs should include the waiver as a condition to approval of new development.

4. Coastal Habitats

The coastal habitats category includes measures designed to protect and enhance coastal habitats, including wetlands, ESHA, and other habitats. Some coastal habitat measures include:

- Use of ecological buffer zones
- Incorporation of sea-level rise in restoration, creation, or enhancement of coastal habitats
- Facilitation of wetland migration
- Increased habitat connectivity
- Open space preservation and conservation
- Protection of ecologically critical areas and species
- Protection of refugia

Table 19. Measures for Natural Resources

Category	Description	Applicability to sea-level rise
Ecological buffer zones	Buffer zones are intended to protect sensitive habitats from the adverse impacts of development and human disturbance. An important aspect of buffers is that they are distinct ecologically from the habitat they are designed to protect.	LCPs can establish requirements for ecological buffers and provide guidance on how to establish or adjust these buffers to accommodate sea-level rise. CDPs should require buffers to be designed, where applicable, to provide "habitat migration corridors" that allow sensitive habitats and species to migrate inland or upland as sea level rises. To accommodate sea-level rise, the amount of buffer required between development and coastal habitats may need to be increased. The size of the buffer needed to allow for migration will vary depending on the individual wetland or habitat type, as well as site specific features such as topography and existing development.
Incorporation of sea-level rise in habitat restoration, creation, and enhancement	Restoration involves returning a degraded ecosystem or former ecosystem to a pre-existing condition or as close to that condition as possible. Creation involves converting one land-use type into another, such as converting dry land into a wetland. Enhancement includes increasing one or more of the functions performed by an existing ecosystem beyond what currently or previously existed.	Habitat restoration, creation, or enhancement projects should be designed to withstand impacts of sea-level rise and adapt to future conditions. As applicable, the LCP should contain policies to ensure restoration and management techniques account for future changes in conditions. CDPs for restoration projects should incorporate sea-level rise and provisions to ensure habitats can adapt with changing future conditions.

Facilitation of wetland migration	Reserve space for a "habitat migration corridor," or areas into which wetlands could migrate as sea-level rise induced inundation of existing wetland areas occurs.	In the LCP, identify potential habitat migration corridors. These areas could be reserved for this purpose in an LCP through land acquisition, use designations, zoning buffers, setbacks, conservation easement requirements, and clustering development. LCPs should also consider developing a plan for acquisition of important habitat migration corridors.
Increased habitat connectivity	Connectivity refers to the degree to which the landscape facilitates animal movement and other ecological flows. Roads, highways, median barriers, fences, walls, culverts, and other structures can inhibit movement of animals.	Develop LCP policies that will enable identification of important animal movement corridors. Develop regulations to protect these corridors for present and future conditions, taking into account habitat shifts from climate change. In LCPs and through CDPs, require that new structures such as highways, medians, bridges, culverts, and other development are designed to facilitate movement of animals.
Open space preservation and conservation	This measure involves preservation of land for its ecological or recreational value. It includes prohibiting development and any uses that conflict with ecological preservation goals.	LCPs can develop open space management plans that evaluate and consider the impacts of sea-level rise, extreme events, and other climate change impacts. LCPs and CDPs can dedicate open space and conservation areas through zoning, redevelopment restrictions, acquisition, easements, setbacks, and buffers.
Protection of ecologically critical areas and refugia	Protect ecologically critical areas, or areas that are important for the continued survival of a species or ecosystem (e.g. nursery grounds, spawning areas, or highly diverse areas) that could be adversely affected by sea-level rise. Also, protect refugia, or areas that may be relatively unaltered by global climate change and thus can serve as a refuge for coastal species displaced from their native habitat due to sea-level rise or other climate change impacts.	LCP land use designations and zoning, and standards for buffers, setbacks, and conservation areas can identify and protect refugia and ecologically-critical areas. Such areas can also be preserved through LCP land use designations and zoning, and standards for buffers, setbacks, conservation easements, and clustering development.

5. Water Quality/ Water Supply Management

Water quality and water supply management measures include actions to minimize adverse impacts to water quality due to sea-level rise, and to prepare for reduced availability of freshwater due to saltwater intrusion. Water quality and water supply management measures include:

- Elimination or reduction of ocean outfall
- Green stormwater infrastructure
- Ground water management
- Limited groundwater extraction from shallow aquifers
- Stormwater management

Table 20. Measures for Water Quality/ Water Supply Management

Category	Description	Applicability to sea-level rise
Elimination or reduction of ocean outfalls	An ocean outfall is a pipeline or tunnel that discharges municipal or industrial wastewater, stormwater, combined sewer overflows, cooling water, or brine effluents from desalination plants to the sea.	LCPs should identify areas where sea-level rise could affect flow of wastewater from outfalls and lead to backup and inland flooding. The LCP can include policies to require modifications to the outfall lines, the use of green infrastructure and redesign of waste and stormwater systems. CDPs for ocean outfalls should consider sea-level rise in design.
Green stormwater infrastructure	Employ natural, on-site drainage strategies to minimize the amount of stormwater that flows into pipes or conveyance systems. These strategies include green roofs, permeable pavements, bioretention (i.e. vegetated swales, rain gardens) and cisterns.	LCPs can include policies that require green infrastructure be used whenever possible in lieu of hard structures. Incorporate sea-level rise and extreme storms into the design.
Ground water management	Plan and coordinate monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of fostering long-term sustainability of the resource.	The LCP can add policies that specify limits on the use of groundwater. These policies should be made in accordance with other regional water planning efforts, such as Integrated Regional Water Plans. CDPs involving the use of ground water should develop a ground water management plan.

Limited groundwater extraction from shallow aquifers	Groundwater extraction from shallow aquifers can increase susceptibility to saltwater intrusion. Limiting or preventing extraction from vulnerable aquifers can reduce the impacts of saltwater intrusion and preserve fresh groundwater supplies.	LCPs or CDPs can add restrictions to the use of aquifers susceptible to saltwater intrusion and can encourage measures to recharge shallow aquifers that are depleted.
Stormwater management	Control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff.	LCPs should include sea-level rise and extreme storms in stormwater management plans and actions. LCPs and CDPs for stormwater infrastructure should consider sea-level rise. Actions to reduce impacts from higher water levels could include widening drainage ditches, improving carrying and storing capacity of tidally-influenced streams, installing larger pipes and culverts, adding pumps, converting culverts to bridges, creating retention and detention basins, and developing contingency plans for extreme events.

6. Additional Actions

Additional actions include measures that the Coastal Commission recommends local governments or applicants consider to minimize risks from sea-level rise but that fall outside of the regulatory authority of the Coastal Act.

- Acquisition and buyout programs
- Modeling and mapping
- Monitoring
- Outreach and education
- Research and data collection

Table 21. Additional Actions

Category	Description	Applicability to sea-level rise
Acquisition and buyout programs	Acquisition includes the acquiring of land from the individual landowner(s). Structures are typically demolished or relocated, the property is restored, and future development on the land is restricted. Undeveloped lands are conserved as open space or public parks.	LCPs can include policies to encourage the local government to establish an acquisition plan or buyout program to acquire property at risk from flooding or other hazards.

Modeling and mapping	Modeling and mapping are tools for assessing climate change impacts and vulnerabilities within a planning area and illustrating potential outcomes of adaptation actions. Modeling enables analysis of potential impacts to an area under various sea-level rise scenarios. Maps portray how sea-level rise scenarios may intersect with coastal and marine resources, community assets and existing social and environmental vulnerabilities.	LCPs should rely upon the best available science in developing sea level guidance. Toward that end, models and mapping tools can be important for determining sea level hazards, and vulnerabilities and can help evaluate the utility of various adaptation strategies. Examples include the NOAA SLR Viewer, Our Coast Our Future, CoSMoS, and the Sea-Level Affecting Marshes Model.
Monitoring	Collect observations or data over time to track changes in the function or condition of a system.	Where appropriate, LCPs can establish regional monitoring programs to track changes in sea level, shoreline or ecosystem status, and the efficacy of adaptation measures. CDPs can require SLR monitoring programs as a condition of approval for more site-specific concerns. Key indicators may include flooding frequency, erosion rate, wave height, tidal range, vertical land movement, sedimentation rate, water quality, etc.
Outreach and education	Outreach includes provision of information to all stakeholders, and occurs at regular intervals throughout the planning and implementation process. It helps to gain support for planning and action implementation. Education involves systematic instruction, through formal systems such as schools or universities. It is important to include all relevant stakeholders in these processes.	For many people, sea-level rise is a new issue. Information on sea-level rise science and potential consequences may be useful in order for stakeholders to take an active role in updating the LCP for sea-level rise issues, or in the vulnerability and risk assessment efforts.
Research and data collection	Create a research agenda to address key data gaps and better utilize existing information.	Pursue new research to better understand the factors controlling sea-level rise, baseline shoreline conditions, ecosystem responses to sea-level rise, potential impacts and vulnerabilities, and the efficacy of adaptation tools.

APPENDIX D. RESOURCES FOR ADDRESSING SEA-LEVEL RISE IN LOCAL COASTAL PROGRAMS

This section contains lists of guidebooks, guidance documents, and state and local efforts underway to prepare for sea-level rise, including tables on:

- Adaptation Planning and Vulnerability Assessment Guidebooks – Table 22
- Examples of Sea-Level Rise Vulnerability Assessments in California – Table 23
- California State Government Resources – Table 24
- Sea-Level Rise Data and Resource Clearinghouses – Table 25
- Resources for Assessing Adaptation Measures – Table 26
- California Climate Adaptation Plans that Address Sea-Level Rise – Table 27

Table 22. Resources for Adaptation Planning and Vulnerability Assessments

Adaptation Planning Guidebooks	Description	Source
Scanning the Conservation Horizon (Grannis, 2011)	Designed to assist conservation and resource professionals to better plan, execute, and interpret climate change vulnerability assessments.	http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use
Adapting to Sea Level Rise: A Guide for California's Coastal Communities (Russell and Griggs, 2012)	Intended to assist California's coastal managers and community planners in developing adaptation plans for sea-level rise that are suited to their local conditions and communities.	http://calost.org/pdf/announcements/Adapting%20to%20Sea%20Level%20Rise_N%20Russell_G%20Griggs_2012.pdf
California Climate Adaptation Planning Guide (EMA and CNRA, 2012)	Provides a decision-making framework intended for use by local and regional stakeholders to aid in the interpretation of climate science and to develop a systematic rationale for reducing risks caused, or exacerbated, by climate change.	http://resources.ca.gov/climate_adaptation/local_government/adaptation_policy_guide.html
Preparing for Climate Change: A Guidebook for Regional and State Governments (ICLEI, 2007)	Assists decision-makers in a local, regional, or state government prepare for climate change by recommending a detailed, easy-to-understand process for climate change preparedness based on familiar resources and tools.	http://www.icleiusa.org/action-center/planning/adaptation-guidebook/view?searchterm

Table 23. Examples of Sea-Level Rise Vulnerability Assessments in California

Climate Vulnerability Studies	Description	Source
Santa Barbara Sea-Level Rise Vulnerability Study (Griggs and Russell, 2012)	Assesses the vulnerability of the City of Santa Barbara to future sea-level rise and related coastal hazards (by 2050 and 2100) based upon past events, shoreline topography, and exposure to sea-level rise and wave attack. It also evaluates the likely impacts of coastal hazards to specific areas of the City, analyzes their risks and the City's ability to respond, and recommends potential adaptation responses.	http://www.energy.ca.gov/2012publications/CEC-500-2012-039/CEC-500-2012-039.pdf
City of Santa Cruz Climate Change Vulnerability Assessment (Griggs and Haddad, 2011**)**	Delineates and evaluates the likely impacts of future climate change on the city of Santa Cruz, analyzes the risks that these hazards pose for the city, and then recommends potential adaptation responses to reduce the risk and exposure from these hazards in the future.	http://seymourcenter.ucsc.edu/OOB/SCClimateChangeVulnerabilityAssessment.pdf
Developing Climate Adaptation Strategies for San Luis Obispo County: Preliminary Vulnerability Assessment for Social Systems (Moser, 2012)	Describes the likely impacts of climate change on the resources and social systems of San Luis Obispo County, and assesses key areas of vulnerability. Sea-level rise is identified as a major source of risk to fishing, coastal tourism, coastal development, and infrastructure.	http://www.energy.ca.gov/2012publications/CEC-500-2012-054/CEC-500-2012-054.pdf
Monterey Bay Sea Level Rise Vulnerability Study (Monterey Bay National Marine Sanctuary and PWA ESA; In progress)	Will assess potential future impacts from sea-level rise for the Monterey Bay region. The project will estimate the extent of future coastal erosion in Monterey Bay due to accelerated sea-level rise and evaluate areas subjected to coastal flooding by inundation from wave action and/or storm surges. The project will update and refine existing Monterey Bay coastal hazard zones maps (erosion and flooding).	Project scope and grant details: http://scc.ca.gov/webmaster/ftp/pdf/sccbb/2012/1201/20120119Board03D_Monterey_Bay_Sea_Level_Rise.pdf

Table 24. California State Government Resources

State of California Resources	Description	Source
California Climate Change Center's 3rd Assessment	Explores local and statewide vulnerabilities to climate change, highlighting opportunities for taking concrete actions to reduce climate-change impacts	http://www.climatechange.ca.gov/adaptation/third_assessment/
California State Sea-Level Rise Guidance Document	Provides guidance for incorporating sea-level rise projections into planning and decision making for projects in California. Updated to include NRC projections March 2013.	http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf
California Climate Adaptation Planning Guide	Provides a decision-making framework intended for use by local and regional stakeholders to aid in the interpretation of climate science and to develop a systematic rationale for reducing risks caused, or exacerbated, by climate change (2012).	http://resources.ca.gov/climate_adaptation/local_government/adaptation_policy_guide.html
2009 California Climate Adaptation Strategy	Summarizes climate change impacts and recommends adaptation strategies across seven sectors: Public Health, Biodiversity and Habitat, Oceans and Coastal Resources, Water, Agriculture, Forestry, and Transportation and Energy. 2012 update should be available by Jan 2013.	http://www.climatechange.ca.gov/adaptation/strategy/index.html

Table 25. Sea-level rise Data and Resource Clearinghouses

Data and resource clearinghouses	Description	Source
California Climate Commons	Offers a point of access to climate change data and related resources, information about the science that produced it, and the opportunity to communicate with others about applying climate change science to conservation in California.	http://climate.calcommons.org/
Climate Adaptation Knowledge Exchange (CAKE)	Provides an online library of climate adaptation case studies and resources, plus ways to connect with an online climate adaptation community/ network.	http://www.cakex.org/
Ecosystem Based Management Tools Network Database	Provides a searchable database of tools available for climate adaptation, conservation planning, sea-level rise impact assessment, etc.	http://www.ebmtoolsdatabase.org/resource/climate-change-vulnerability-assessment-and-adaptation-tools

Table 26. Resources for Assessing Adaptation Measures

Adaptation Strategies	Description	Source
General		
Georgetown Climate Center's Climate Adaptation Toolkit – Sea-Level Rise and Coastal Land Use	Explores 18 different land-use tools that can be used to preemptively respond to the threats posed by sea-level rise to both public and private coastal development and infrastructure, and strives to assist governments in determining which tools to employ to meet their unique socio-economic and political contexts.	http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use
Strategies for Erosion-Related Impacts		
Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay	Provides a technical evaluation of various erosion mitigation measures, conducts a cost benefit analysis of some of the more promising measures, and includes recommendations for addressing coastal erosion in Southern Monterey Bay. The report is intended to be relevant for other areas of California as well.	http://montereybay.noaa.gov/new/2012/erosion.pdf
Rolling Easements		
Rolling Easements- A Primer (Titus 2011)	Examines more than a dozen different legal approaches to rolling easements. It differentiates opportunities for legislatures, regulators, land trusts, developers, and individual landowners. Considers different shoreline environments (e.g. wetlands, barrier islands) and different objectives (e.g. public access, wetland migration)	http://papers.risingsea.net/rolling-easements.html
No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast (Caldwell and Segall 2007)	Provides a description of sea-level rise impacts to ecosystems and public access, strategies to address these impacts, and case study examples of rolling easement strategies for the California coast.	http://www.boalt.org/elq/documents/elq34-2-09-caldwell-2007-0910.pdf

Natural Resources		
PRBO Climate Smart Conservation	Lists science-based, climate-smart conservation planning and management tools and methods, including restoration projects designed for climate change and extremes.	http://www.prbo.org/cms/650
US Forest Service System for Assessing Vulnerability of Species- Climate Change Tool	Quantifies the relative impact of expected climate change effects for terrestrial vertebrate species.	http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/savs-climate-change-tool/

Table 27. California Climate Adaptation Plans that Address Sea-Level Rise

Example Climate Adaptation Plans	Description	Source
Adapting to Rising Tides (ART) Project	The ART project is a collaborative planning effort led by the San Francisco Bay Conservation and Development Commission to help SF Bay Area communities adapt to rising sea levels. The project has started with a vulnerability assessment for a portion of the Alameda County shoreline.	http://www.adaptingtorisingtides.org/ Vulnerability and risk assessment report: http://www.adaptingtorisingtides.org/vulnerability-and-risk-assessment-report/
Santa Cruz Climate Adaptation Plan	An update to the 2007 Hazard Mitigation Plan, the adaptation plan includes strategies and best available science for integrating climate change impacts into City of Santa Cruz operations.	Complete plan is available: http://www.cityofsantacruz.com/Modules/ShowDocument.aspx?documentid=23643
San Diego Bay Sea Level Rise Adaptation Strategy	The strategy provides measures to evaluate and manage risks from sea-level rise and other climate change impacts, and includes a vulnerability assessment of community assets at risk, and broad recommendations to increase resilience of these assets.	http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance/san-diego-bay-sea-level-rise-adaptation-strategy-1/san-diego-bay-sea-level-rise-adaptation-strategy

APPENDIX E. EXAMPLES OF SEA-LEVEL RISE PREPARATION FROM OTHER STATE AGENCIES

Many state agencies have developed, or are in the process of developing guidance on suggested actions to prepare for sea-level rise relevant to their organization. Some of these guidance documents are described below in Table 28. The table includes a brief description of the documents and the sea-level rise projections used.

Table 28. California State Agency Sea-Level Rise Policy Guidance Documents

Agency	Name and date of document	Description
California Natural Resources Agency	Safeguarding California from Climate Change: update to 2009 Climate Adaptation Strategy	The California Natural Resources Agency, in coordination with other state agencies, is in the process of updating the 2009 Climate Adaptation Strategy. This update will augment previously identified strategies in light of advances in climate science and risk management options. The update is planned for release to the public as a draft for comment by the end of 2013. For more information, visit: http://www.climatechange.ca.gov/adaptation/strategy/index.html
Coasts & Oceans Climate Action Team (led by Ocean Protection Council)	California State Sea-Level Rise Guidance Document (2013)	Provides guidance for incorporating sea-level rise projections into planning and decision making for projects in California. Updated to include NRC projections March 2013. Available: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf
California Coastal Conservancy	Climate Change Policy (2010)	Includes policies on 1) Consideration of climate change in project evaluation 2) Consideration of sea-level rise impacts in vulnerability assessments, 3) Collaboration to support adaptation strategies, 4) Encouragement of adaptation strategies in project applications mitigation and adaptation. Available: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/
	Project Selection Criteria (2011)	Adds sea-level rise vulnerability to project selection criteria. Criteria available: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/

	Guidance for addressing climate change in CA Coastal Conservancy projects (2012)	Includes the following steps: 1) Conduct initial vulnerability assessment, 2) Conduct more comprehensive vulnerability assessment, 3) Reduce risks and increase adaptive capacity, and 4) Identify adaptation options. Available: http://scc.ca.gov/2013/04/24/guidance-for-grantees
San Francisco Bay Conservation and Development Commission (BCDC)	Climate Change Bay Plan Amendment (2011)	Amends Bay Plan to include policies on climate change and sea-level rise. Policies require 1) a sea-level rise risk assessment for shoreline planning and larger shoreline projects. 2) If risks exist, the project must be designed to cope with flood levels by mid-century, and a plan to address flood risks at end of century. Assessments are required to "identify all types of potential flooding, degrees of uncertainty, consequences of defense failure, and risks to existing habitat from proposed flood protection devices." Available: http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml
	"Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline" (2009)	Provides the background staff report identifying vulnerabilities in the Bay Area's economic and environmental systems, as well as the potential impacts of climate change on public health and safety. The report provides the basis for all versions of the proposed findings and policies concerning climate change. Available: http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf
California Department of Transportation (CalTrans)	CalTrans Climate Change Adaptation Hot Spot Map (in development)	Goal is to create a GIS-based assessment of transportation infrastructure vulnerabilities using available data and studies and to identify critical transportation hotspots (areas of increased vulnerability due to population, travel, or climate effects). This research will also result in the development of a climate vulnerability plan that will assess the level and type of transportation infrastructure vulnerability, the adaptation options and strategies, and a framework for prioritizing implementation efforts (in development). More information available: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/projects_and_studies.shtml

	Guidance on Incorporating Sea Level Rise (2011)	Provides guidance on how to incorporate sea-level rise concerns into programming and design of CalTrans projects. Includes screening criteria for determining whether to include SLR and steps for evaluating degree of potential impacts, developing adaptation alternatives, and implementing the adaptation strategies. Available: http://www.dot.ca.gov/ser/downloads/sealevel/guide_incorp_slr.pdf
	Addressing Climate Change in Regional Transportation Plans: A Guide for MPOs and RTPAs (2010)	Provides a clear methodology for regional agencies to address climate change impacts through adaptation of transportation infrastructure. Available: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf#zoom=65
State Lands Commission	Application for Lease of State Lands (2011)	Requires assessment of climate change risks, and preference is given to projects that reduce climate change risks. Available: http://www.slc.ca.gov/Online_Forms/LMDApplication/Lease_App_Form_2011.pdf
California State Parks	Sea-level rise guidance (in development)	Will provide guidance to Park staff on how to assess impacts to parklands.

APPENDIX F: COASTAL ACT POLICIES RELEVANT TO SEA-LEVEL RISE AND COASTAL HAZARDS

F.1 Legislative Findings Relating to Sea-Level Rise

Section 30006.5 of the Coastal Act states (Legislative findings and declarations; technical advice and recommendations) states (emphasis added):

> *The Legislature further finds and declares that sound and timely scientific recommendations are necessary for many coastal planning, conservation, and development decisions and that the commission should, in addition to developing its own expertise in significant applicable fields of science, interact with members of the scientific and academic communities in the social, physical, and natural sciences so that the commission may receive technical advice and recommendations with regard to its decisionmaking, especially with regard to issues such as coastal erosion and geology, marine biodiversity, wetland restoration, the <u>question of sea-level rise</u>, desalination plants, and the cumulative impact of coastal zone developments.*

F.2 Public Access and Recreation

Section 30210 of the Coastal Act (Access; recreational opportunities; posting) states:

> *In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.*

Section 30211 of the Coastal Act (Development not to interfere with access) states:

> *Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.*

Section 30212 of the Coastal Act (New development projects) states:

> *(a) Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where: (1) it is inconsistent with public safety, military security needs, or the protection of fragile coastal resources, (2) adequate access exists nearby, or (3) agriculture would be adversely affected. Dedicated accessway shall not be required to be opened to public use until a public agency or private association agrees to accept responsibility for maintenance and liability of the accessway.*

Section 30214 of the Coastal Act (Implementation of public access policies; legislative intent) states:

> (*a) The public access policies of this article shall be implemented in a manner that takes into account the need to regulate the time, place, and manner of public access depending on the facts and circumstances in each case including, but not limited to, the following:*
> *(1) Topographic and geologic site characteristics.*

(2) The capacity of the site to sustain use and at what level of intensity.

(3) The appropriateness of limiting public access to the right to pass and repass depending on such factors as the fragility of the natural resources in the area and the proximity of the access area to adjacent residential uses.

(4) The need to provide for the management of access areas so as to protect the privacy of adjacent property owners and to protect the aesthetic values of the area by providing for the collection of litter.

(b) It is the intent of the Legislature that the public access policies of this article be carried out in a reasonable manner that considers the equities and that balances the rights of the individual property owner with the public's constitutional right of access pursuant to Section 4 of Article X of the California Constitution. Nothing in this section or any amendment thereto shall be construed as a limitation on the rights guaranteed to the public under Section 4 of Article X of the California Constitution.

(c) In carrying out the public access policies of this article, the commission and any other responsible public agency shall consider and encourage the utilization of innovative access management techniques, including, but not limited to, agreements with private organizations which would minimize management costs and encourage the use of volunteer programs.

Section 30220 of the Coastal Act (Protection of certain water-oriented activities) states:

Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas shall be protected for such uses.

Section 30221 of the Coastal Act (Oceanfront land; protection for recreational use and development**)** states:

Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

Section 30223 of the Coastal Act (Upland areas) states:

Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.

F.3 Wetlands and Environmentally Sensitive Resources

Section 30231 of the Coastal Act (Biological productivity; water quality) states in part:

The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored…

Section 30233 (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:*

Section 30240 of the Coastal Act (Environmentally sensitive habitat areas; adjacent developments) states:

> *(a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.*
>
> *(b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Coastal Act Section 30121 defines "Wetland" as follows:

> *"Wetland" means lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.*

The California Code of Regulations Section 13577(b) of Title 14, Division 5.5, Article 18 defines "Wetland" as follows:

> *(1) Measure 100 feet landward from the upland limit of the wetland. Wetland shall be defined as land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes, and shall also include those types of wetlands where vegetation is lacking and soil is poorly developed or absent as a result of frequent and drastic fluctuations of surface water levels, wave action, water flow, turbidity or high concentrations of salts or other substances in the substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deep-water habitats. For purposes of this section, the upland limit of a wetland shall be defined as:*
>
> *(A) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover;*
> *(B) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or*
> *(C) in the case of wetlands without vegetation or soils, the boundary between land that is flooded or saturated at some time during years of normal precipitation, and land that is not.*
>
> *(2) For the purposes of this section, the term "wetland" shall not include wetland habitat created by the presence of and associated with agricultural ponds and reservoirs where:*
>
> *(A) the pond or reservoir was in fact constructed by a farmer or rancher for agricultural purposes; and*
> *(B) there is no evidence (e.g., aerial photographs, historical survey, etc.) showing that*

> *wetland habitat pre-dated the existence of the pond or reservoir. Areas with drained hydric soils that are no longer capable of supporting hydrophytes shall not be considered wetlands.*

In addition, Coastal Act Section 30107.5 defines "Environmentally sensitive area" as follows:

> *"Environmentally sensitive area" means any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.*

F.4 Agricultural and Timber Lands

Section 30241 of the Coastal Act (Prime agricultural land; maintenance in agricultural production) states:

> *The maximum amount of prime agricultural land shall be maintained in agricultural production to assure the protection of the areas' agricultural economy, and conflicts shall be minimized between agricultural and urban land uses…*

Section 30242 of the Coastal Act (Lands suitable for agricultural use; conversion) states:

> *All other lands suitable for agricultural use shall not be converted to nonagricultural uses unless (1) continued or renewed agriculture use is not feasible, or (2) such conversion would preserve prime agricultural land or concentrate development consistent with Section 30250. Any such permitted conversion shall be compatible with continue agricultural use on surrounding lands.*

Section 30243 of the Coastal Act (Productivity of soils and timberlands; conversions) states:

> *The long-term productivity of soils and timberlands shall be protected, and conversions of coastal commercial timberlands in units of commercial size to other uses or their division into units of noncommercial size shall be limited to providing for necessary timber processing and related facilities.*

F.5 Archeological and Paleontological Resources

Section 30244 of the Coastal Act (Archaeological or paleontological resources) states:

> *Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required.*

F.6 Marine Resources

Section 30230 of the Coastal Act (Marine resources; maintenance) states:

> *Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy*

> *populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.*

Section 30231 of the Coastal Act (Biological productivity; water quality) states:

> *The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface waterflow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.*

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects…*
>
> *(d) Erosion control and flood control facilities constructed on watercourses can impede the movement of sediment and nutrients that would otherwise be carried by storm runoff into coastal waters. To facilitate the continued delivery of these sediments to the littoral zone, whenever feasible, the material removed from these facilities may be placed at appropriate points on the shoreline in accordance with other applicable provisions of this division, where feasible mitigation measures have been provided to minimize adverse environmental effects. Aspects that shall be considered before issuing a coastal development permit for these purposes are the method of placement, time of year of placement, and sensitivity of the placement area.*

Section 30234 of the Coastal Act (Commercial fishing and recreational boating facilities**)** states:

> *Facilities serving the commercial fishing and recreational boating industries shall be protected and, where feasible, upgraded. Existing commercial fishing and recreational boating harbor space shall not be reduced unless the demand for those facilities no longer exists or adequate substitute space has been provided. Proposed recreational boating facilities shall, where feasible, be designed and located in such a fashion as not to interfere with the needs of the commercial fishing industry.*

Section 30234.5 of the Coastal Act (Economic, commercial, and recreational importance of fishing) states:

> *The economic, commercial, and recreational importance of fishing activities shall be recognized and protected.*

F.7 Coastal Development

Section 30250 of the Coastal Act (Location; existing developed area) states:

(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.
(b) Where feasible, new hazardous industrial development shall be located away from existing developed areas.
(c) Visitor-serving facilities that cannot feasibly be located in existing developed areas shall be located in existing isolated developments or at selected points of attraction for visitors.

Section 30251 of the Coastal Act (Scenic and visual qualities) states:
The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas...

Section 30253 the Coastal Act (Minimization of adverse impacts) states in part:
New development shall do all of the following:
(a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.
(b) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs...

Section 30235 of the Coastal Act (Construction altering natural shoreline) states:
Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible.

Section 30236 of the Coastal Act (Water supply and flood control) states:
Channelizations, dams, or other substantial alterations of rivers and streams shall incorporate the best mitigation measures feasible, and be limited to (l) necessary water supply projects, (2) flood control projects where no other method for protecting existing structures in the flood plain is feasible and where such protection is necessary for public safety or to protect existing development, or (3) developments where the primary function is the improvement of fish and wildlife habitat.

F.8 Ports

Section 30705 of the Coastal Act (Diking, filling or dredging water areas) states:

> *(a) Water areas may be diked, filled, or dredged when consistent with a certified port master plan only for the following: …*
> *(b) The design and location of new or expanded facilities shall, to the extent practicable, take advantage of existing water depths, water circulation, siltation patterns, and means available to reduce controllable sedimentation so as to diminish the need for future dredging.*
> *(c) Dredging shall be planned, scheduled, and carried out to minimize disruption to fish and bird breeding and migrations, marine habitats, and water circulation. Bottom sediments or sediment elutriate shall be analyzed for toxicants prior to dredging or mining, and where water quality standards are met, dredge spoils may be deposited in open coastal water sites designated to minimize potential adverse impacts on marine organisms, or in confined coastal waters designated as fill sites by the master plan where such spoil can be isolated and contained, or in fill basins on upland sites. Dredge material shall not be transported from coastal waters into estuarine or fresh water areas for disposal.*

Section 30706 of the Coastal Act (Fill) states:

> *In addition to the other provisions of this chapter, the policies contained in this section shall govern filling seaward of the mean high tide line within the jurisdiction of ports:*
>> *(a) The water area to be filled shall be the minimum necessary to achieve the purpose of the fill.*
>> *(b) The nature, location, and extent of any fill, including the disposal of dredge spoils within an area designated for fill, shall minimize harmful effects to coastal resources, such as water quality, fish or wildlife resources, recreational resources, or sand transport systems, and shall minimize reductions of the volume, surface area, or circulation of water.*
>> *(c) The fill is constructed in accordance with sound safety standards which will afford reasonable protection to persons and property against the hazards of unstable geologic or soil conditions or of flood or storm waters.*
>> *(d) The fill is consistent with navigational safety.*

Section 30708 of the Coastal Act (Location, design and construction of port related developments) states:

> *All port-related developments shall be located, designed, and constructed so as to:*
>> *(a) Minimize substantial adverse environmental impacts.*
>> *(b) Minimize potential traffic conflicts between vessels.*
>> *(c) Give highest priority to the use of existing land space within harbors for port purposes, including, but not limited to, navigational facilities, shipping industries, and necessary support and access facilities.*
>> *(d) Provide for other beneficial uses consistent with the public trust, including, but not limited to, recreation and wildlife habitat uses, to the extent feasible.*
>> *(e) Encourage rail service to port areas and multicompany use of facilities.*

F.9 Public Works Facilities

According to Coastal Act Section 30114, public works facilities includes:

> *(a) All production, storage, transmission, and recovery facilities for water, sewerage, telephone, and other similar utilities owned or operated by any public agency or by any utility subject to the jurisdiction of the Public Utilities Commission, except for except for energy facilities [which are regulated by the Public Utilities Commission].*
>
> *(b) All public transportation facilities, including streets, roads, highways, public parking lots and structures, ports, harbors, airports, railroads, and mass transit facilities and stations, bridges, trolley wires, and other related facilities. For purposes of this division, neither the Ports of Hueneme, Long Beach, Los Angeles, nor San Diego Unified Port District nor any of the developments within these ports shall be considered public works.*
> *(c) All publicly financed recreational facilities, all projects of the State Coastal Conservancy, and any development by a special district.*
> *(d) All community college facilities.*

F.10 Greenhouse Gas Emissions Reduction

Section 30250(a) of the Coastal Act (Location, existing developed areas states) in part:

> *(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.*

Section 30252 of the Coastal Act (Maintenance and enhancement of public access) states:

> *The location and amount of new development should maintain and enhance public access to the coast by (1) facilitating the provision or extension of transit service, (2) providing commercial facilities within or adjoining residential development or in other areas that will minimize the use of coastal access roads, (3) providing nonautomobile circulation within the development, (4) providing adequate parking facilities or providing substitute means of serving the development with public transportation, (5) assuring the potential for public transit for high intensity uses such as high-rise office buildings, and by (6) assuring that the recreational needs of new residents will not overload nearby coastal recreation areas by correlating the amount of development with local park acquisition and development plans with the provision of onsite recreational facilities to serve the new development.*

Section 30253(d) of the Coastal Act (Minimization of adverse impacts) states in part:

> *New Development shall:*

(d) Minimize energy consumption and vehicle miles traveled….